FINDING PARALLELS: ADVANCING CREATIVITY AND INNOVATION IN ENGINEERING THROUGH THE VISUAL ARTS

By

KATHRYN F. LALLEMENT

A CAPSTONE PROJECT PRESENTED TO THE COLLEGE OF FINE ARTS OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF ARTS

UNIVERSITY OF FLORIDA

2013
Acknowledgements

I would like to first thank my husband, David Lallement, and daughter, Stella Lallement for being my biggest fans and believing in me; this would not have been possible without their support. I would also like to thank my mom, Diane Fallon, who came to my rescue several times throughout this process and always “understood”. I would like to thank Dr. Keith Plemmons and Dr. John Murden for their insights and enthusiasm for my research. I would also like to thank my committee member, Dr. Craig Roland, who always got me to “dig-deeper,” bought me a coffee when I needed it most, and who always looks out for the well-being of his students. My deepest appreciation and gratitude goes to my committee chair, Dr. Elizabeth Delacruz who has been my untiring guide and without whose amazing knowledge, extreme patience, and constant help, this Capstone would not have been possible. Finally, it has been my great honor and privilege to have worked with my father, Dr. Dennis Fallon. I would like to thank him for his support, excellent advice, laughter, and fantastic stories.
My capstone project stemmed from conversations that I, an art educator, began with my father who is a professor in engineering. My research investigates background information outlining the recent history of engineering and how art-related skills in engineering are currently taught. It examines the current trend of project-based lessons in the classroom as an attempt to integrate more creativity and problem-solving skills into the engineering curriculum. My research explores the connection of visual art practices and engineering through sketching, visualization, model making, and exploration of spatial relationships. It also examines the
problems and impediments the inclusion of arts-based creative learning activities can bring to the engineering classroom and curriculum. Methods used in this research included semi-structured and informal interviews. I conclude this Capstone research paper with insights that pose the skills and inquiry processes that are basic to art education as beneficial to the education of engineering students.

I created several products to support this research. This included a blog, found at www.klallement12.blogspot.com. My blog captures my thinking and emerging findings as this study unfolded. I also created over thirty original images for this project. I curated two archives of resources on Pinterest.com that include images and articles that are related to science, engineering, and the visual arts. My Pinterest boards are viewable on http://www.pinterest.com/katelallement/art-and-engineering/. I also created a Scoop.It archive of readings informing my topic at http://www.scoop.it/t/art-and-engineering, and an electronic picture book, published in ISSUU at http://issuu.com/katelallement/docs/art_engr. This picture book recounts in narrative style some of my insights, conversations, and interviews with engineering professors, each juxtaposed by one of my original images created for this project.

My website houses my gallery of original images, along with links to my other creative products mentioned above. My website is viewable at http://lallement12.wix.com/artengr.

Keywords: engineering, visual arts, art education, problem-solving, creativity
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Conversations

For as long as I can remember, I have been the only “known” artistic person in my family and have always felt a little misunderstood. Until I started teaching, I never thought that I had much in common with my father, Dr. Dennis Fallon, who is a professor in engineering at the Citadel in South Carolina. My pursuit of college degrees in Horticulture, French, and Studio Arts have been jokingly commented on by my father who asked when I would start studying “real” subjects like engineering. Living close and seeing each other frequently, I was out to prove to my father (in good fun) the significance of art. As an art educator, I do this all the time with my students to show them how what they are taking can contribute to their overall education. This would be a challenge with my father, as I knew very little about engineering and engineering education. While trying to convince my father about the worth of art study as my goal, I started linking different aspects of engineering to my knowledge about art.

Over a year ago my father and I began long weekly conversations in which we would discuss education, art, and engineering. Dad mentioned a real need in American Engineering—a need for more creative and innovative students. Seeing also a need to demonstrate the significance of visual arts and how it could enhance creativity and innovation, I expressed my interest in researching the benefits of art education in engineering for my Master’s Degree Capstone Project through the University of Florida and together we started this journey. This research is much more than a look into art education and its relationship with engineering. Much like my father and I, being male and female and from different generations, my work is a look into two subjects that are perceivably at different ends of the professional spectrum. Through this inquiry I attempt to show how these two perceivably different subjects share similar problems and what advancements we might make in both fields if we collaborate.
Problem Statement and Goals

With exponential increases in technology and communication, our world is becoming smaller. Countries such as China and India are graduating large amounts of engineers every year. In 2005, the United States graduated 70,000 engineers compared to India at 350,000 and China at 600,000 (Kiwana, Kumar, & Randerson, 2012). What sets engineering in the US apart from Engineers in other countries in the world? The US has excellent engineering programs and schools already in place nation-wide, however, the field of engineering and the needs of society are changing beyond the programs currently in place. In my research, I consider why engineers must develop creative and problem-solving skills. I identify art skills and inquiry processes that are already found or thought to be needed in the undergraduate engineering classroom, and when enhanced, how such art skills and inquiry processes might better prepare engineering students for the 21st century workplace. My research also identifies some obstacles to integrating visual arts skills and inquiry processes into the undergraduate engineering curriculum.

There may be general thought amongst the US public that engineering students are taught what they need to know to immediately start working professionally upon graduation. After all, a B.S. degree in engineering is considered a professional degree (Wulf, 1998). In actuality, many engineering firms require one post-baccalaureate year of on-the-job training before they feel new candidates are ready to take on real-life engineering problems (Foley & Kazerounian, 2007). Students graduating as engineers with bachelor’s degrees in engineering usually spend a year or two completing their “studies” on the job (Dym, Agogino, Eris, Frey & Leifer, 2005). What skills are not taught or developed in the university undergraduate engineering program? Do art-related educative skills fill a gap in the undergraduate education of the engineering student? Research suggests that artistic creativity and creative problem-solving skills are highly
underestimated and underdeveloped in engineering schools (Felder, 1988; Dym, Agogino, Eris, Frey & Leifer, 2005) and that the engineering professional would benefit greatly if creative problem solving were more directly addressed in their undergraduate studies. Scholars argue that such skills and dispositions would strengthen ingenuity and innovation on the job (Santamarina & Akhoundi, 1991). Based on the aforementioned beliefs, the purpose of my study is to develop a rationale for teaching and learning art-based creative and design processes in undergraduate engineering programs of study. This study shows relationships to skills learned in visual arts and design and engineering, outlining similarities in thinking processes across these fields. It will consider the views of faculty who favor divergent thinking with faculty who favor convergent thinking in engineering departments.

**Research Questions and Assumptions**

I believe that together, engineering professors with art and design faculty could develop creative, professionally ready engineering graduates to better society and address twenty-first century problems. Using informal interviews and semi-structured interviews as my primary method of inquiry, research questions that guided my inquiry were:

1. How can engineering programs teach art-based, creative, and critical thinking skills to new engineering students?

2. How are the visual arts and engineering connected?

3. What current trends are found in the engineering classroom as an attempt to integrate more creativity and problem solving skills?

I further believe that the development of visual arts skills and inquiry processes in the engineering undergraduate curriculum could enhance engineering learning, creativity, and innovation.
Rationale and Significance of the Study

The development of programs in secondary schools that promote STEM (Science, Technology, Engineering, and Mathematics) is gaining popularity in the US. Some educators have expanded the STEM initiative to include the significance of art education. These scholars and educators have modified the STEM initiative to become STEAM, which includes an “A” in the acronym to include the arts (Bequette & Bequette, 2012). Such initiatives have stimulated investigations into the relevance of creativity and innovation taught and learned through the visual arts to other core subjects in k-12 school settings (Bequette & Bequette, 2012). Scholars observe that creativity and divergent thinking need to be developed in undergraduate university courses as well, especially in subjects that involve innovation and problem-solving like engineering (Adams, Kaczmarczyk, Picton, & Damian, 2007; Felder, 1988). My study adds to this ongoing conversation about the role and value of visual arts education in relation to other subjects, including and in particular engineering.

Supporting Literature

This literature review will discuss selected themes and findings emerging from my readings. These themes include ideas about creativity in engineering, visual arts skills and processes that are found in engineering, and project-based learning activities used in the engineering classroom. These themes provided me a context for understanding as I pursued my research questions.

The Problem of Creativity in Engineering Learning

Looking for creativity in the profession of engineering was one of the main concerns that motivated my research. Right away, for me, it seemed that both art and engineering are creative. My readings about creativity led me to conclude that this was a broad and varyingly defined
concept, but creativity is describable, nevertheless. Zimmerman (2009) observes, “Many contemporary psychologists and educators agree that creativity is a complex process that can be viewed as an interactive system in which relationships among persons, processes, products, and social and cultural contexts are of paramount importance” (p. 386). As I dove deeper into the topic I noticed parallels between the visual arts and engineering regarding the need for creativity. Scholars such as Dr. Richard M. Felder have advocated for creative and innovative learning in the field of engineering. Felder (1987) writes, “It would seem to be our (engineering professors) responsibility to produce some creative engineers—or at least not to extinguish the creative spark in our students” (p. 222). In his article “Creativity in Engineering Education,” Felder (1998) suggests characteristics to look for in creative students. These characteristics include “independence, inexhaustible curiosity, tolerance of ambiguity in problem definitions, willingness to take risks, persistence in pursuit of problem solutions, and the patience to allow the solutions to take shape in their own time” (p. 6). He explains that many professors don’t or aren’t able to see these characteristics because of the analytical manner of most engineering classroom activities (Felder, 1988).

Creativity may be thought of as both a process and a way of thinking. Convergent and divergent thinking are both necessary for the practice of engineering. Convergent thinking is defined by Merriam-Webster as “thinking that weighs alternatives within an existing construct or model in solving a problem or answering a question to find one best solution” (Merriam-Webster’s online dictionary, 2013). This type of thinking is found in analytical, solution-

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1 Dr. Richard M. Felder (1987) is well known in the field of engineering. He is Hoechst Celanese Professor Emeritus of Chemical Engineering at North Carolina State University in Raleigh, North Carolina. His articles express interests in educational reform in engineering, placing the responsibility and change on the engineering professor.
oriented, problem solving endeavors in engineering learning. Divergent thinking is a kind of thinking associated with open-ended and multi-solution problems. Merriam-Webster defines divergent thinking “…creative thinking that may follow many lines of thought and tends to generate new and original solutions to problems…” (Merriam-Webster’s online dictionary, 2013). The problem lies not in types of thinking engaged, but in goals sought. Adams, Kaczmarczyk, Picton and Demian (2007) observe, “Excellence in engineering problem solving is synonymous with skill at convergent production since engineering education normally involves only problems with a single correct answer. However, this is not particularly true of engineering practice in general” (p. 2). This statement demonstrates a problem in engineering education, that is, the goal to produce a single correct answer. Yet writings indicate a need for creative and innovative engineers to solve societal problems today and in the future (Santamarina & Akhoundi, 1991; Stouffer, Russell, & Oliva, 2004; Felder, 2008). Engineers need to be good problem solvers, able to solve both problems that are analytical in nature and problems that may have more than one solution. Stouffer, Russell, & Oliva (2004) claim “What ‘normal’ civil engineers do is inherently creative, as comparisons between the creative process and the design process demonstrate. The same can be said for chemical, electrical, industrial, mechanical, and systems engineers” (p. 22).

Kazerounian and Foley (2007), authors of “Barriers to Creativity in Engineering Education: A Study of Instructors and Students Perception” stress the value of arts based learning in engineering classes. In their examination of the significance of the relationships

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2 Dr. Kazerounian is currently the interim dean for the department of engineering at the University of Connecticut. His current active research includes creativity in engineering education amongst other interests in the engineering field. Stephany Foley, is currently a Mechanical Engineering Designer and Project Manager at LIGO Lab at Massachusetts Institute of Technology.
between creativity, the college professor, and the student, they found that engineering professors are resistant to creative work finding the work not serious-minded. They also found that current engineering education can suppress creative characteristics. They established that the environment can suppress creativity in students and changing this environment can foster more creativity in the engineering learning (Kazerounian and Foley, 2007).

**Visual Skills Found in Engineering**

Through my readings it is apparent that the development of visual art skills such as drawing, sketching, model-making, and spatial relationship skills are considered to be essential to engineering problem-solving, analyzing, and communication. These skills are developed during the last two years of the engineering undergraduate program and are typically taught by university and college engineering professors. Spatial and visual ability can be described in engineering by orthographic (two dimensional) images, “created by theoretical projections of the object onto perpendicular reference planes” (Voland, 1987, p.83). An example of spatial and visual ability in drawing is the ability to render the orthographic drawing of a pictorial concept or model (Voland, 1987). Being able to translate a two-dimensional object to a three-dimensional object and vice-versa is necessary especially in mechanical, civil, and structural engineering. For engineers, being able to “see” the whole picture as it relates to a project is indispensable.

Engineers often use sketches in communicating plans and projects between engineers and clients or non-engineers. Engineering sketching or freehand drawing is defined by Voland (1987) as, “…drawing without the use of instruments” (p. 381). Voland asserts that the engineer, “must be able to graphically record and communicate ideas with speed in the absence of drawing equipment” (1987, p. 381). Drawings can be simple or highly detailed and can include various lines, dimensions, and symbols.
Communication is a big part of engineering practices. For example, an engineer needs to communicate ideas to other engineers, clients, and to contractors. Through sketching and drawing these ideas are visually represented. Therefore, the better the drawing, the better the communication. Dr. Joakim Juhl\textsuperscript{3} and Hanne Lindegaard (2013) looked closely at sketching, visualization and design skills found in the visual arts and how they relate to engineering practices. They found representations to be an important part of engineering learning. Moreover, representations aid in the transfer of knowledge and ease the “actual synthesis” in the design process (Juhl & Lindegaard, 2013, p. 47). Juhl and Lindegaard (2013) suggest that working in collaborative groups when learning observational drawing is significant to engineering. They also observe that more research is necessary regarding visual representation in engineering education.

**Project-Based Learning**

Another area where we see visual arts and design skills being practiced in the undergraduate engineering classroom is in project-based learning encounters. Project-Based Learning is used as a means for motivating the student and enhancing the engineering program by providing engineering students with real world scenarios, problems, and learning experiences that involve collaboration and communication (Dym, Agogino, Eris, Frey, & Leifer, 2005).\textsuperscript{4} Project-Based Learning is defined by the Buck Institute of Education as “a systematic teaching method that engages students in learning essential knowledge and life-enhancing skills through

\textsuperscript{3} Dr. Juhl is a Postdoctoral Fellow at the Program on Science, Technology & Society. His current research centers on how the roles of models and simulations can be interpreted as a characteristic mode of mediation between science, technology and society at the Harvard Kennedy School of Government at Harvard University.

\textsuperscript{4} Project-Based Learning should not be confused with Problem-Based Learning (also abbreviated as PBL), which is also found in engineering learning.
an extending student-influenced inquiry process structured around complex authentic questions and carefully designed products and tasks” (The Buck Institute, 2013, para. 7). These skills include “communication and presentation skills, organization and time management skills, research and inquiry skills, self-assessment and reflection skills, and group participation and leadership skills” (The Buck Institute, 2013, para 3). Dym, Agogino, Eris, Frey, & Leifer (2005) suggest that project based learning addresses transfer in the cognitive science in their observation that, “transfer,” which may be defined as the ability to extend what has been learned in one context to other contexts” (p. 110).

**Model Engineering Programs**

There are programs in engineering schools that I looked at as exemplary models that incorporated engineering techniques with activities in creativity, sketching, visualization, model-making, and exploration of spatial relationships. Some examples include but are discussed below.

**SCOPE.** Seniors at Olin College of Engineering participate in a Capstone project, SCOPE (Senior Capstone Program in Engineering). The SCOPE project is a partnership with industry to develop and provide solutions industries may need. With their culminating experience of Olin students' education, students work in collaborative groups for the duration of their senior year (http://scope.olin.edu/about/). The Olin SCOPE project engages engineering students to creatively solve-real world problems. Students working on the SCOPE project work with not only Olin University faculty but also have company advisors. Students are allowed to work in the on campus art facility and are provided well-furnished workspaces to complete their projects. Some examples of companies that have provided this collaboration are Boeing, Facebook, Harley Davidson, and Trip Advisor.
**Lego Engineering.** This project was developed by the Tufts Center for Engineering for Engineering Education and Outreach (CEEO). Engineering schools like Tufts University (http://ceeo.tufts.edu/), Clemson University (http://www.clemson.edu/ces/departments/ece/undergrad/mindstormslab.html), and the University of Nevada-Reno (http://www.unr.edu/nevada-today) are engaging students with LEGO projects. Students build robots and other creatively designed constructions using LEGO parts and computer chips that are programmable, and that move and perform specific timed tasks. These projects engage not only creativity and problem solving in engineering by taking inanimate objects and making them animated but also are fundamental to the art practices of sketching, drawing, and visualization for project planning and design, since students are asked to visualize and sketch ideas as part of the process. The LEGOEngineering website (http://www.legoEngineering.com/) also contains information for engineering instructors teaching at K-12 schools.

**Concrete Canoe.** Engineering schools all over the world participate in concrete canoe racing. In the Southeast US, engineering schools such as The Citadel, University of South Carolina, Clemson, and North Carolina State University participate in a yearly concrete canoe race. Engineering students are asked to collaborate to build a canoe out of concrete. After designing the frame of the boat and creating the light-weight concrete, students race the canoes hoping that they will float. Taking pride in their creation more often than not, students also paint the canoe showing their school’s pride. Constructing the concrete canoe allows students to participate in problem-solving, collaborative, visual arts skills with drawing, painting, and sketching plans and ideas. Taken together, these examples exemplify creativity, visual art skills, and project-based learning. They are informed by the same kinds of skills and inquiry processes
that are fundamental to Art, therefore showing a true collaboration of real-world experiences with art and engineering.

**Research Methodology**

My research methods for this capstone project included informal and semi-structured interviews and purposive expert sampling methods. The purposive sampling method is a method of sampling where the researcher knows what needs to be researched and identifies for interviews or surveys specific individuals who have expertise in the particular field of inquiry being researched (Tongco, 2007). I also relied on my literature review to both help me better understand undergraduate engineering programming concerns and to identify and examine models that crossed over into what I believe to be methods and concepts that are also fundamental to art making. My interview subjects included three engineering professors, Dr. Dennis J. Fallon, Dr. Keith Plemmons, and Dr. John Murden. Each have given consent to be participants in this study. They have also consented to have their names used. To prepare for these interviews, I examined contemporary engineering writings concerning the incorporation of creativity, visual art skills, and problem-based learning in the engineering curriculum. I also looked for model programs in engineering. My goal was to identify programs that engage the visual arts or art-based learning. My readings of published research pertaining to my topic helped me identify areas of convergence between engineering and visual arts education.

**Informal Interviews**

I began this research project many months before my research officially started. Since becoming an art educator and pursuing my Masters degree, my father (an engineering professor) and I have had numerous conversations about crossovers between the professions of art, engineering, and education. These conversations were the basis for subsequent informal
interviews with my father. These informal interviews acted like a guide to my research. We looked at my research questions, themes, and topics of research. The interviews took place weekly during a six-month period in 2013, and would vary in time from ten minutes to two hours. We also communicated through email. I documented these informal interviews with my father by taking notes. Seeing my father so often allowed me to go back and ask further questions if I needed him to elaborate. I also kept the emails we would send in case there were any questions. Emails also allowed us to send journal articles to one another for further research. My reflections and analysis of these informal interviews provided a basis for my semi-structured interviews with two other engineering professors.

**Semi-Structured Interviews**

Semi-structured interviews are interviews that originate with a list of topics or questions pre-determined by the researcher prior to the interview. However, the interview in itself is flexible as long as it answers the questions or topics (Heiman, 2001). Answers to questions led to probing and follow up questions, and sometimes these interviews took off in directions that deviated from my original list of questions. My semi-structured interviews sought to know how three current professors in the field of engineering apply skills also commonly found in the visual arts (like drawing, sketching, observation, spatial relationships, and creativity) to their classroom curriculum. Each of my semi-structured interviews lasted over an hour. The interviews took place at the Citadel in Charleston, South Carolina and at the Low Country Graduate Center in North Charleston, South Carolina. Interviews were audio recorded and transcribed. I took notes during the interviews as a means to identify things that seemed important during the interviews. Questions for the semi-structured interviews were sent via email
prior to the interview. The questions I asked came from my research questions and included the following:

1. How do you see the visual arts and engineering connected?

2. How do engineering programs teach art-based, creative, and critical thinking skills to new engineering students?

3. What current trends are found in the engineering classroom as an attempt to integrate more creativity and problem-solving skills?

I also felt it was necessary to ask a fourth question:

4. What can visual artist learn from engineers (or design in engineering)?

Subjects

My informal interviews were conducted exclusively with my father, Dr. Dennis Fallon. My other subjects for the semi-structured interviews were Dr. Keith Plemmons and Dr. John Murden, professors in Engineering at the Citadel in Charleston, South Carolina. These subjects were purposively selected on the basis of their expertise, experience, interest in the topic, and willingness to talk to me. The Citadel is a renowned conservative military college in Charleston, SC. My first thoughts about my capstone proposal were to collect data from up to nine Citadel engineering faculty. This became a problem with summer scheduling and time conflicts. A smaller number of interviewees helped me narrow down data collection for this research.
Dr. Dennis Fallon, my father, earned a Ph.D. from North Carolina State University (see Figure 1). He has over eleven years of industrial experience designing transmission structures and commercial and industrial buildings. He has over thirty years of teaching experience at the graduate and the undergraduate level. He is also a fellow of the American Society of Civil Engineers and a Fellow in the American Society of Engineering education. He served for ten years as Department Head of Civil and Environmental Engineering as well as eight years as the founding Dean of Engineering at the Citadel. He has served in various leadership roles for the American Society for Engineering Education. He is a licensed professional engineer and a
project professional in addition to having served on the state board for the registration of engineers and land surveyors.

Figure 2. Dr. Keith Plemmons

Dr. Keith Plemmons has extensive industrial experience in Project Management (see Figure 2). In addition, he has extensive experience in higher education teaching the principles of Project Management, Risk Assessment, and Quality Assurance and Control. He has had over twenty years of experience teaching the fundamental principles of program and project management at the undergraduate and graduate level. He is currently an Associate Professor at the Citadel in the School of Engineering. He is a Professional Engineer and Project Management Professional.
Dr. John Murden has a PhD from Clemson University and has been teaching at the undergraduate level in the Civil and Environmental Department at the Citadel for over twenty seven years (see Figure 3). His area of expertise and research interests are Structural Mechanics, Structural Analysis, Computer Simulation, and Fluid Analysis. His special interests lie in developing computer models using stochastic analysis. He expressed high interest in my research stating a need for the visual arts connection in engineering and suggested I continue after graduation.
**Data Collection**

The first stage of this process was to inquire “How are the visual arts and engineering connected?” One connection I sought was through examination of ideas about creativity and innovation. I examined scholarly research and writings by scholars that have extensive knowledge in the field of engineering and innovation in engineering. As my research developed, I started to realize that there were other elements in the visual arts that could be found in or were important to engineering. Through my readings about creativity and innovation in engineering, I found drawing and sketching, spatial relationships, and visualization to be important foundations that lead to creativity and innovation in engineering. Seeing the relationship between these visual arts skills to creativity and innovation; I slightly shifted my research from focusing primarily on creativity to these considerations. Most of my readings were from engineering scholars. Surprisingly, I found it difficult to find readings about creativity and innovation in the sciences (including engineering) written by art education scholars in higher education. The articles I found written by art education scholars dealt with the K-12 program and pertained mostly to the STEM to STEAM movements (Bequette & Bequette, 2012).

During the second stage of my research, as my focus shifted, I developed and refined my interview questions. I felt it was better to ask engineering professors about the professional training development of engineers in universities rather than to pose questions to practicing engineers. The continuing conversations with my father and review of relevant studies helped with the development and refinement of my interview questions. I focused my questions to engineering professors, asking if they thought there were examples or interest in integrating visual arts skills or processes into the engineering curriculum, and what was lacking in the development of these visual arts skills as such skills pertained to engineering tasks. I wanted to
know how these current engineering professors incorporate creativity and skills such as drawing, sketching, observation, spatial relationships, and art inquiry processes in their curriculum. I also wanted to know how these engineering professors felt about recent trends in innovation in the field of engineering and what kinds of knowledge (if at all) an educator in the visual arts could bring to student learning in engineering programs of study.

Data Analysis

My findings have been derived from data collected, analyzed, and reviewed from the readings and from my informal and semi-structured interviews with selected engineering faculty. Once I had conducted the interviews, I identified patterns and relationships from my records of these interviews (Boyce & Neale, 2006). For the informal and semi-structured interviews, analysis included organizing my topics, questions, and recurring statements (from the interviews) into broad categories. I looked and found common responses (Guion, Diehl, & McDonald, 2001) from the engineering professors I interviewed. I looked for relationships in responses to organize and interpret data from the interviews (Boyce & Neale, 2006). Some of my interview data collected did not fit into broad categories and I was able to create additional substantive categories to analyze data and look for similar data in my readings (Maxwell, 2004). Using triangulation methods (Maxwell, 2004), triangulating interview data across my three subjects and creating a synthesis matrix (Maxwell, 2004). Creativity, common skills found in both art and engineering, design study, and project-based learning emerged as central themes of interest in my synthesis matrix. In addition, subjects were contacted for member-checking as recommended by Carlson (2010). I returned to my interviewees for clarifications and to verify that I interpreted their responses correctly. This procedure proved to be invaluable as I refined my findings.
Limitations

There are several limitations to my research. The first limitation is my knowledge and understanding of engineering. My knowledge is limited to scholarly literature, interviews and surveys, and my personal relationship to my father who is a current professor in engineering. Another limitation is time allowed for further research and data collecting. Limitations of the semi-structured interviews include the location in which my subjects work. The subjects teach at a conservative school in South Carolina and may hold traditional views. An additional limitation is the subject of creativity. Creativity is difficult to define and can be interpreted in many different ways. Also, there are more aspects of engineering that can be related to visual arts than those mentioned in this research and should be further explored. It is my hope that findings emanating from my research motivates future research into relationships between art and engineering education.

Discussion of Findings

A key finding of my research is that innovation and creativity, aspects thought to be central to art, are also important to engineering and engineering learning. From my research I surmise that inquiry processes central to the visual arts can play an important aspect in providing engineering students with opportunities to engage in divergent thinking, use their imagination, innovate, and create. The visual arts also employ important skills such as sketching, rendering, modeling, and communicating visually.

Creativity and Innovation for the Future of Engineering

The experience of a visual arts education can “expose us to many tantalizing examples of ambiguity and to a lot of sensations and to forms of perception which do not exist in the normal realm of Science and Engineering” (Shuster, 2008, p. 97). My first finding was that in order to
solve future world problems, there is a great need for creative and innovative engineers. To do this, the use of both divergent and convergent thinking is fundamental in improving in engineering innovation and engagement with newly emerging, unusual problems emanating from real world issues is essential. Current engineering students are taught to solve traditional problems that are pre-determined by their engineering teachers, problems that have one solution. They are not necessarily current problems with multiple solutions. One conversation that I had with my father helped me with this insight. He observed “Students are not deviating from the norm. They are using pre-determined, provided questions and answers and not really learning to solve problems with more than one solution” (D. Fallon, personal communication, September 2013). One of my readings (Shuster, 2008) reconfirms this insight with “If we focus our intentions too strongly on solving problems in only our chosen discipline, in which the range of perception and expression is limited-especially so in Engineering and Science-then we lose suppleness in our thinking, as well as insights that often come from obscure analogies” (p. 98). Pre-determined question and solution instruction does not aid in solving problems that have yet to exist or solving problems with no known solution.

**Fundamentals of Visual Arts Skills in Engineering**

Skills learned in the visual arts, design, and engineering have similarities. Skills I identified in my research and found to be important to engineering include but are not limited to visualization, spatial relationships, and drawing and sketching. Esparragoza (2004) defines visualization by “… the ability to process and interpret visual information and to generate visual ideas that can be transformed into concrete drawings and objects” (p. 77). These skills became more evident in the articles I read on creativity. Visual art skills like drawing and sketching found in engineering that can aid in the advancement of creativity and innovation but can also
aid in communication and collaboration. Juhl and Lindegaard (2013) write, “The activity of drawing translates individual cognitions into a process of collective re-cognition” (p. 33). In my email communication with Dr. Juhl, he noted, “…the traditional engineering curriculum promotes and emphasizes engineering sciences and monodisciplinary skills and gives less priority to important collaborative skills such as sketching and visualization” (J. Juhl, personal communication, September 13, 2013). Visualization and spatial relationships are important to observation, good drawing, and in the translation of three-dimensional and two-dimensional objects. It is important that engineering students are able to do this. If these visual art skills like drawing and observation are enhanced in engineering learning, they can not only aid in observational skills but improve visualization and understandings of spatial relationships. Esparragoza (2004) states, “The ideal situation for engineers is not only to process the visual information fast but to enhance visualization skills to be used in the design process and in the solution of engineering problems” (p. 77).

Drawing and sketching play a big part in communication in engineering. The better the visual, the better the communication. Communication is essential to good engineering. An engineer needs to be able to communicate the big ideas of an architect or designer to other engineers or construction contractors to make the idea practical and function properly. Professional engineers need to communicate the functionality of objects to people that may not understand engineering terminology. Good drawing abilities aid in communicating those ideas.

**Project-Based Learning in Engineering Studies**

The inclusion of creative learning activities helps bring real-life professional experiences to the engineering classroom. Seeing a need for creativity in engineering schools, an example of a creative learning activity is with project-based learning. The advantages to project-based
learning for students are listed by Stouffer, Russell, and Oliva (2004) as, “increased critical thinking, increased self-direction, higher comprehension and better skill development, self-motivated attitudes, enhanced awareness of the benefits of teamwork and a more active and enjoyable learning process” (as cited in Johnson, 1999, para. 33). These advantages are proven to be reasons for incorporating and learning visual arts in secondary education. Some engineering professors and programs have developed exciting project-based learning (PBL) approaches as a way to develop these skills. However, the use of PBL is not consistent in engineering programs. Engineering professors that have themselves been taught more analytically and methodologically do not see PBL as a critical part of learning (Dym, Agogino, Eris, Frey, & Leifer, 2005). Some engineering professors believe that these types of lessons are created for accreditation purposes only and have little or no value to engineering education.

Others believe that PBL oriented learning has additional value. In engineering programs, student retention and motivation is a major issue (Dym, Agogino, Eris, Frey, & Leifer, 2005). Engineering students fail to gain critical thinking skill through the common practice of only analytical and mechanical problem-solving (D. Fallon, personal communication, September, 2013). Project-based learning bridges student learning to real-world problem solving and adds excitement to otherwise monotone lessons (Dym, Agogino, Eris, Frey, & Leifer, 2005). Stouffer, Russell, and Oliva (2004) believe that project-based learning is an essential tool to encouraging creativity in engineering students.

**Challenges and Impediments in the Engineering Curriculum**

There are many aspects to engineering learning that share similar features with learning in the visual arts. Creativity, sketching, visualization, model-making, design, design thinking, and visual spatial relationships are all found to be valued skills found in visual arts that aid in
engineering innovation, creation, and communication. In my research, I found that there are current engineering institutions and programs that see some value to such interests and approaches; however, these areas are under-developed. Moreover, engineering schools may be asking engineering professors (individuals with little or no experience in art) to be the ones teaching these valued artistic skills and processes to students. Art faculty are specialized and trained to develop these skills and could help engineering professors teach these skills and better prepare students for their professional careers as Engineers

It would seem as if the problems discussed here could be an easy fix. Engineering curriculum designers could modify the engineering curriculum so that more time would be devoted to the development of professional problem-solving, and art-related, and creative skills. Unfortunately, to add art, design, or creative processes-oriented courses to an already overloaded engineering curriculum is not feasible. Standalone courses could add too much pressure to an already charged curriculum. For example, some undergraduate engineering programs already have requirements up to 130 hours for graduation. At the same time, states are requiring those institutions to scale down to 120 hours (Wulf, 1998). In response, programs of study in engineering tend to eliminate humanities courses (including the arts) when more fundamental courses are required (Wulf, 1998). Another major difficulty with teaching art and design-based skills is changing the engineering faculty’s perceptions about art education. In most engineering programs, course requirements include little or no artistic courses, design thinking courses, or courses devoted to creativity. Even when the engineering curriculum includes design courses as fundamental to the program, these courses are often taught in an analytical manner by engineering professors.
The question that remains, then, is how can engineering programs teach art-based, creative, and critical thinking skills to new engineering students? It is widely recognized that university studio art and design courses involve and develop creative thinking skills, visual skills, collaboration, and problem-solving. Rather than adding new courses to an already overcrowded engineering curriculum, rethinking certain courses in the engineering curriculum may be one solution. Selected engineering courses could incorporate methodologies learned in the visual arts and design fields. Art and design faculty could easily teach creative generating skills in short mini-lessons or problems within existing courses, or they could be engaged as consultants to engineering professors wishing to integrate some creative and art/design-related learning encounters into an existing course. In fact, some engineering schools have hired design faculty to help teach these design courses. Unfortunately, problems arise when design faculty are not viewed as equals to Engineering faculty (Dym, Agogino, Eris, Frey, & Leifer, 2005). I believe that through sustained, collaborative relationships between faculty from these diverse disciplines such prejudices would dissipate over time. Innovative, successful models resulting from such collaborations would set the stage for future integration of the art skills and inquiry processes into engineering problems that students are asked to solve.

Insights and Speculations

As a high school instructor in the visual arts, I am constantly advocating the importance of Art. I explain to my friends and colleagues how the study of visual arts is valuable to society and how the visual arts relate to every subject of study and how they can benefit students’ futures. I started this research by having conversations with my father. Through this investigation, I wanted to further identify and describe some of the relationships between the visual arts and engineering. Moreover, I wanted to make a case for the significance of visual arts
education in engineering education. The conversations I had with selected experts (engineering professors) were inspiring both to my research and to me personally, in terms of how I regard Engineering (and the sciences) and my perspective on my own subject—the visual arts. My father continues to encourage me in everything I do and when I decided to do this research, I had his full support. Not knowing much about engineering myself, his thoughts on innovation and creativity in Engineering aided my understandings. He feels the future leaders of engineering will need to be good innovator and the development of visual art skills like those mentioned in my research, can play a major role in the future of engineering. Together, we have decided to continue researching the benefits of the visual arts in engineering in the near future.

The conversation I had with Dr. Keith Plemmons was also eye-opening. Dr. Plemmons remarked that he saw the visual arts as important to engineering learning as a way of documenting transactions during the creation process in case something goes wrong and there is a need to problem shoot. He also commented that he saw the ability to imagine risks or imagine what could go wrong as important to engineering learning and felt that visual art skills could increase such abilities. Personally, I have never associated risk and imagination and found that to be extremely enlightening. Dr. Plemmons feels like the visual arts help people connect with the world around them and that in engineering the visual arts can help people see the big picture.

In my conversation with Dr. John Murden, he identified key observational skills in both engineering and art skills. These fundamental skills facilitate construction, interpretation, innovation, and presentation of plans and information. He also observed that the biggest benefits to Engineering via art education are to help students with visualizing problems in a way that they can take problems apart for analysis.
Finally, my last expert was unexpected. When I wrote an email to Dr. Juhl after being inspired by an article he wrote for the *Journal of Engineering Education*, I was extremely surprised at the warm response I received. His offer to help and his direction to other resources were appreciated. His article aided me in my research and had me thinking about sketching, visualization, and design skills in visual arts. Dr. Juhl wrote, “Engineering is also an art, as art is also a kind of Engineering. Modern disciplinary thinking tends to make us think as if disciplinary boundaries were essential. They are not, they are constructed and reconstructed all of the time” (J. Juhl, personal communication, September 13, 2013). This statement reiterated the benefits of visual Art skills in engineering learning.

**My Creative Products**

Using traditional art making, digital imaging, and online social media sites, I have created a variety of creative products for my research. These include a website, a blog, a Scoop.it archive, a Pinterest Board, and a gallery of original images. I briefly describe these creative products in the following sections. Each of these products is available online. Readers are encouraged to follow the web links provided in each of my descriptions of these products.

*My website.* My website is my main repository for this research project (see Figure 4). It contains links to my Capstone paper, my blog (Blogster), my curated, annotated social media collections that include Scoop.it (for essays and websites) and Pinterest (for images), an online gallery of original images that I created as this project progressed, and a link to my e-book (ISSUU). Both the images and buttons appearing on my website are linked to the various other products that I created for my research. The website provides a central location and a unified visual format linking to all of my varying creative projects resulting from this research ([http://lallement12.wix.com/artengr](http://lallement12.wix.com/artengr)).
My images. My project includes a gallery of original artworks that I created as I was pursuing this research (see Figure 5, and also go to my online gallery at (http://lallement12.wix.com/artengr#!gallery/c14zg). When making these images I was encouraged by my mentor for this capstone to continue creating them as I was thinking about, talking to my subjects about, and reading about my capstone project. My goal went from finishing twenty-five images to completing over thirty images. The making of these images gave me creative space in which to think about the many questions, readings, interviews, and emerging findings that occupied much of my time. Creating original artwork for this capstone project was a highpoint for me.
To make these images, I took photographs and overlaid them onto engineering blueprints I found in my father’s office. There were several reasons why I used engineering blueprints that I found in my father’s office. I wanted to establish a visual relationship between the photos I took and engineering concepts. I could have done this with just an image but felt like using engineering blueprints and the lines that were created by someone else (even if it was computer generated) help make this connection. Line happens to be a focus in my personal work so it seemed fitting to allow the engineering lines to weave in and out of my figures. Secondly, I found these in a closet in my father’s office and liked the idea that they were once used by him and I would recycle them and turn them into something special. I struggled with the idea to add color to my body of work but felt the contrasts of black and white-two opposites- went with my ideas of two seemingly different subjects and two different generations that really go together.

To keep the images flat for photographing, I spray-mounted each of them onto mat board. When I presented my work to my father, I was perturbed that he was busily studying the blueprints in the background of the image and not the image in its entirety. I made a point to say to him that he needed to look at the whole image not just the background. After thinking about it, that’s what the visual arts does; it allows you to see the whole picture. Sometimes it isn’t the just what is on the surface or what you can touch but what is beneath the surface that counts. There are multitudes of thoughts and feelings that go into making works of art.
My e-book (ISSUU). My e-book was a big motivator in completing my images. I wrote and self-published a “picture-book” sharing insights from my study, using an online e-book site called ISSUU and including some of my original images that I had created (see Figure 6). The images and text created for this book narrate my conversations with my father as I dove into my research questions. My book describes who I am and who my father is being that he is an important part of my research. It travels through each research question asking my father, then Dr. Plemmons and Dr. Murden their thoughts. I also added a personal communication I received
from Dr. Juhl. My first goal was to have at least twenty-five images for my book. Then to narrate the e-book, I played with the images I had created, deciding which image would go where. As I started putting the book together, I struggled with the layout and colors. I wanted a simplistic look that focused on the writing and images but also looked interesting and of quality. I finally chose a landscape design with the left page a white background with black font and the right page a black background with the centered image. I used iBook software for Macintosh, then published the fifty-five page book on ISSUU (http://issuu.com/katelallement/docs/art_enr).

Social media curated annotated collections. Through the collection of images and ideas on two social media sites, Pinterest (see Figure 7) and Scoop. It (see Figure 8), I was able to
collect information and organize and ideas that linked ideas in the visual arts and engineering, and in some cases the sciences. Pinterest is primarily an image repository, designed to look like a pinboard. With Pinterest, I was able to collect imagery that pertained to teaching and inspiring ideas for my research topic. I also found works of art that were inspired by these connections. Some of the images I collected were artworks by engineers and artists, new and innovative concepts and some images contained project ideas for adults and children (http://www.pinterest.com/katelallement/art-and-engineering/).

Using a social media site called Scoop.it (see Figure 8), I also collected inspirational captions and aphorisms about the two fields. Scoop.it is a site where people may create
repositories of collected articles and websites, formatted to display like an electronic magazine. Scoop.it allowed me to collect and organize articles that pertained to the fusion or crossovers of arts and engineering. I was astonished by how many articles I was able to find and how many people have taken interest in this topic. It is my hope that this curated collection will help to further research about how the visual arts contribute to innovation and creativity in engineering ([http://www.scoop.it/u/kate-lallement12](http://www.scoop.it/u/kate-lallement12)).

![Figure 8. Scoop.it](image)

*My blog.* Finally, one of the things I did to facilitate my thinking as this research project unfolded was to keep a blog (see Figure 9). To be honest, I was initially resistant to keeping a blog. Before this Capstone project, I found blogs to be for people that had lots of time. When it
was suggested that I keep one, I said I would. I was surprised to be wrong in my initial assumption. The purpose of my blog was to house a record of my thoughts and feelings through the images I photographed. Some of the photographs in my blog became image inspirations for my e-book. As I finished an image, I would post that image on my blog. My blog also allowed others to connect and comment on my posts as my research progressed. The duration of my blog was from August 2013 to November 2013. During my semi-structured interview with Dr. Plemmons he stated how the visual arts provided a means for documenting transitions and “landmarks”. I find this statement to be true. What I had documented in my blog guided me in the narration for the book. It also allowed me to now see this research endeavor holistically and how it developed over time (http://klallement12.blogspot.com/).
Some Final Thoughts

I began this study wanting to find out how art education might be useful in engineering programs of study. What I have also learned through this study is that engineering is not just the scientific and analytical field that is perceived to be. It is also very creative, artistic, and in some cases misperceived as only methodical and analytical. Engineering, although publicly perceived only as a non-creative, analytical, and methodological subject, is creative, like the visual arts. Engineers advance, develop, redefine, and produce for society’s needs. I agree with William Wulf (1998) who asserts, “Science is analytic—it strives to understand nature, what is.
Engineering is synthetic—it strives to create what can be” (p. 21). The Visual Arts, in some cases, are also misperceived as being a pastime, frivolous, or not a contributor to education. My research shows neither is true. These close relationships found in Engineering and in Visual Arts suggest a need to better integrate art and design thinking skills and art education practices in engineering learning. I would argue it would be necessary to re-conceptualize the engineering undergraduate curriculum to integrate these skills and practices so that they may benefit innovation and creativity in future Engineering. I also concluded that emphasizing visual arts in the engineering curriculum can also help build and benefit the significance of art education. I believe that this study strongly suggests a need for engineering faculty who favor open ended problem solving, artistic visualization, divergent thinking, and collaboration with their colleagues in art and design education. More research should be undertaken regarding what the visual arts bring to education in other fields such as Engineering in the post-secondary universities and colleges. There is much to be learned from Engineering that might inform art education practices. Finally, my simple conversations with my father have contributed not only to my research but to me in a very personal way. I have gotten to know my father better both personally and professionally and that we, like our subjects, are not so different after all and have many of the same parallels.
References


List of Figures with Figure Captions

Figure 1. Lallement, Kathryn. 2013. Dad: Dr. Dennis Fallon. Illustration.

Figure 2. Lallement, Kathryn. 2013. Dr. Keith Plemmons. Illustration.

Figure 3. Lallement, Kathryn. 2013. Dr. John Murden. Illustration.

Figure 4. Lallement, Kathryn. 2013. Screenshot of Website.

Figure 5. Lallement, Kathryn. 2013. Screenshot of Gallery.

Figure 6. Lallement, Kathryn. 2013. Screenshot of E-book

Figure 7. Lallement, Kathryn. 2013. Screenshot of Pinterest Board.

Figure 8. Lallement, Kathryn. 2013. Screenshot of Scoopit collection.

Figure 9. Lallement, Kathryn. 2013. Screenshot of Blog
Author’s Biography

Kathryn Lallement holds an Associate’s degree in Horticulture, a Bachelor’s in Studio Arts and graduated with honors to earn her Bachelor’s in French. Voted Teacher of the Year in 2009-2010, she’s a dedicated instructor of the arts at Pinewood Preparatory School in Summerville, S.C. Kathryn demonstrates her leadership skills by serving on the Curriculum Committee, Lower School Leadership board, and the SCISA committee for Pinewood. In 2010, she moved from lower school to teach high school and Advanced Placement. Kate believes that everyone has the ability to become an active learner and art can be a means of learning how to achieve that goal. Fascinated with the field of Engineering and how art can boost creativity and innovation, her current research interests are with finding relationships found in Engineering and Art. Captivated by technology, she is also is interested in researching the role of technology in art-making and Engineering in the future.

Outside of the classroom, Kate continues to work on her own art. She enjoys exploring positive and negative space with the subjects she portrays. Kate finds herself particularly drawn to the simplicity of the Asian line and aspires to bring that simplicity to her own work. She is inspired by the Asian arts, James McNeill Whistler, works by abstract expressionists Franz Kline and Wiliam de Kooning, and modern artist Shepard Fairey.