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Developing Creativity Through Enhanced Communication and Teamwork in Engineering

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Future engineers will need to address problems through multiple lenses and consider solutions that stray from the most efficient linear consideration (Cropley, 2016). “Engineering has never been more competitive. Emerging from the recession, engineering firms are leaner than ever and accustomed to achieving more with less, satisfying more demands from clients, and meeting shorter deadlines” (Crawford, 2012, 1). To prepare future generations for the expanding expectations of the profession, curricula must be intentionally designed to provide experiences that expand considerations through intersections with variety of educational areas. Student competency in creativity, communication, and teamwork are among desired qualifications for engineering graduates (Claris & Riley, 2013; Burrack, 2017) that can be developed through curricular innovation.

Creativity development within engineering curricula

Universities are increasingly expected to provide more opportunities that foster and nurture creativity in engineering students (Baillie, 2002). Intentional teaching of creativity in engineering is an ongoing concern in the sense that it helps meet the expectations of professional preparation (Liu & Schonewetter, 2004). Implementation of creativity education in engineering curricula has not been fully realized in many programs across the country (Cropley, 2015). Fostering creativity in engineering students requires an understanding of the creative process in context. The Creativity in Arts, Science and Engineering (CASE) project suggested that creative potential lies dormant in most students until an instructor unblocks barriers and ignites creativity through creative experiences (Dewulf & Baillie, 1999). According to Treffiner (1995), purposefully teaching for creativity enables students to learn about their own creative abilities and attain greater personal and professional success in the areas in which the creative efforts are applied. Unfortunately, little has been done in many universities to place teaching emphasis on developing and facilitating creativity in their engineering students (Cropley & Cropley, 2000; Cropley, 2015).

Experimentation has begun during the past decade to bring together students from liberal studies and engineering areas to learn together in problem-solving teams. This trend immerses students in interdependent, cross-disciplinary discourses to promote curiosity, creativity and innovation. For example, music could be reframed as signals produced by one or a group of systems within the context of electrical engineering. Learning outcomes can be focused on conceptual commonalities while addressing knowledge expectations of both music and electrical engineering. These commonalities reflect how engineers consider a signal, its frequency spectrum, its energy content, and the information contained, while musicians consider four elements of music—rhythm, melody, harmony and timbre. Music is an organization of audio signals. Organizational considerations of melody, harmony and rhythm are not entirely different from frequency, amplitude and time; they simply constitute a variance of perspective. In a project supported by a National Science Foundation grant, Head, Burrack, & Dyer (2013), the question of how to unlock creative potentials in developing engineering students was explored. That study took place in an interdisciplinary course developed at two large R1 universities.

This study reported successful learning of electrical engineering learning outcomes with students demonstrating enhanced consideration toward creativity processes, teamwork skills, and communication strategies. Further investigation into interdisciplinary collaboration was suggested for future research.

The project

This study took place in courses over a three-year time period. The purpose was to identify learning that resulted from interdisciplinary coursework and curricular interactions for students from the fields of electrical engineering and music composition. Research questions used to focus the study were: (a) To what extent do the participants recognize connections between music, music composition, and electrical/computer engineering prior to experiencing the course?; (b) In what way do cross-disciplinary understandings transform within the first two weeks of interdisciplinary experience?; (c) What do participants consider in respect to the role of imagination and creativity in their discipline?; (d) What educational contributions are exhibited and described by the participants?; and (e) What new learning do participants perceive as contributing to professional goals?

Participants

The participants were forty first-year electrical and computer engineering majors (n=23) and undergraduate music majors (n=17). The course, titled *Signals, Systems and Music,* addressed the topics of electronic-signal analysis and generation with learning demonstrated through creative music composition. The course treated topics from a holistic perspective. For electrical engineering students, the course was a general-education elective. For the music students, the course was required for composition majors and an elective for other music majors. Coursework assignments in the Signals, Systems and Music course were designed as electrical engineering problems to solve by creating and manipulating the sound signal for a prescribed purpose in the development of musical compositions. Each assignment required creativity, communication, and teamwork among music and electrical and computer engineering students. Although theories of creativity are supported by a variety of scholarly approaches, Craft (2005) suggested that creativity in an educational setting includes a relationship between knowledge, curriculum, and pedagogy that enables creativity to be developed or reawakened.

Procedures

Students were exposed to concepts fundamental to both music and engineering, emphasizing the interconnectedness of the disciplines. Learning expectations focused upon:

a) understanding the historical relationship of the electronic manipulation of sound and the relevance of that relationship for the creation of music;
b) understanding the basic physics of sound as it relates to what is perceived as musical sound;

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c) applying skills in electronic generation of musical sounds and how to duplicate or transform traditional musical sounds to create new electronic sounds;
d) using a variety of sound-modification devices and techniques in the creation and realization of short musical pieces;
e) exhibiting a conceptual understanding of how the elements of music (e.g., rhythm, melody, harmony, and timbre) relate to elements of engineering (e.g., frequency spectrum, amplitude distribution, energy content, and information) and how they relate to the creative organization that occurs within a musical composition and engineering constructs;
f) organizing traditional, manipulated, and created sounds into a musical composition that clearly integrates the musical and engineering elements in a purposefully creative and aesthetic arrangement; and
g) recognizing the interplay between musical and technological imaginations through music and signal processing.

Expanding consideration of creative boundaries was one of the intended outcomes of this course. This was assessed through a pre- and post-survey of students': (a) perception of learning in their discipline, (b) educational and professional goals, and (c) concept of professional needs beyond the classroom in their future profession. Pre-course, mid-term, and exit interviews were also employed to identify educational impact of the course and its instructional methods. Responses were transcribed and coded into categories of the questions, as well as emergent topics. When necessary, emergent issues resulted in follow-up interviews. All reports were member-checked to expose researcher misunderstanding and ensure authentic representation of student experience. Assignments included: (a) producing a C sound instrument connecting mathematical signals to the physical quantities materialized as sound in a variety of timbre; (b) building a signal through additive synthesis using Matlab; and (c) organizing traditional, manipulated, and created sounds into a short musical composition that clearly integrated the musical and engineering elements and creatively used a variety of sound-modification devices and techniques.

Analysis and Findings

At the beginning of the course, the engineering students expressed excitement about exploring his or her "creative side, which is not so well developed. We don't get as much of a chance to explore this area in our curricular program." Many of the engineering students were familiar with expectations of completing structured assignments, but were challenged when allowed the autonomy of choosing the process and structure of assignments. They described training in the field of engineering as including limited coursework that allows creative freedom, or even reference to the development of creative abilities: "There aren't a lot (of courses) that even allude to creativity. It is very subtle when it is included in the curriculum." One of the engineering students clearly described a sentiment to which many of those involved in the project alluded:

> Creativity in engineering is kind of a standing joke. I know they want us to possess creativity but thinking outside of the box is not what we do. I remember once we took a personality test in one of our classes and all engineers fell two-thirds of the distance away from creativity. We are taught to think in a linear way, to find the most efficient and

> economical way to move from one point to another. The type of creativity involved in music is starting from scratch and sometimes throwing out the established way to create a new way. That is very difficult for us to do for fear of penalty of failing.

As the study progressed, the engineering students demonstrated some frustration in achieving the flow of creative intention as observed in their musician counterparts:

> Moving beyond established rules is a new thought for me. I observed the musicians compose beyond prescribed rules or common norms. I am beginning to realize that to do something different and possibly end up with something great, I would need to take a risk at maybe doing something terrible. I guess that is where creativity plays into engineering, which is one of the things that attracted me to this course in the first place. I can get straight A's in my classes without using a lot of creativity because that is the way the engineering curriculum is set up. They want to make sure we learn to follow a process. But in order to be a good engineer, we will have to break from the established lines of thought. Although this is something important to my greater success as an engineer, it has not explicitly been taught or developed in my engineering training. I have had some teachers say that in order to be really good you are going to have to do something more than what you are doing in this class, hinting at the importance of creativity, but it is not something that has been actively cultivated. That would require we stop crunching numbers for a few weeks.

Even though engineering students expressed ambiguity associated with the creative process in engineering coursework, a definite awareness of how creativity will be important in their future was apparent: "If I'm going to be a successful engineer, I have to come up with something that no one else has designed, or to think about solutions that haven't yet been tried and tested. That is the way we get new technologies." A tension between engineering students' perception of learning-needs as compared to their perception of training received to that point was evident. The gap appeared to elicit desires for learning that could fulfill this need:

> As I work with my music-major partner and when I'm in my engineering mode, it appears that my brain shuts off. Then I observe the musician in a creative thought process and what I observe is amazingly free flowing and creative. This interests me because it is something I desire. By observing and working together I not only expand how I think but to also understand other people, which is what I will need once I work on projects in the field.

Part of the attraction of experiencing creativity centered upon interdisciplinary teamwork:

> I took this class because I thought it would be very interesting to work together with someone that thinks fundamentally different than I. As an engineer, I'm a process-based thinker. In my consideration, I begin with a start-point, gather information, then apply my understandings of a process that leads to an end point.

The difference in thinking processes utilized during creative problem-solving was discussed by both engineering and music students in this interdisciplinary experience. Many inferred that creativity is not different in definition between disciplines, but the process through which it is achieved is unique. "After our first class period, it is very interesting to experience the different ways of thinking and how we interact to generate ideas that I had not considered, and probably would not have." Originally, the engineering students considered the creative process as a framework of stability and practicality whereas the musicians used creativity to discover what was beyond current considerations. But interacting with the creative process within another's framework was precisely what the engineers had described as a perceived deficiency for their future success.

The creative experience for the engineering students was not only encountered in process, but clarified in created product. Although not surprising to the musicians, the result of the compositions being unique in every way was astonishing to the engineers: "I am amazed that no composition remotely resembled another's project. In many engineering classes, there are only so many ways that projects can be done, so in the end many usually have identical results." The open-ended process without a specified endpoint was easily accepted by the musicians but challenging to the engineering students who often asked for a specified sequence and clarified expectations during the development of the final product:

> It was difficult working on the composition without having some guidance with parameters. But looking back, this struggle forced us to make our own decisions on what parameters we want. I'm used to reaching a goal around designated guidelines. It would been easy if we had been given a checklist of things for each assignment, but being asked to make a composition without specific parameters forced us to make decisions on our own. It enabled us to be creative in ways that may not have been achieved if we had to meet certain criteria. The experiences, in many ways, were liberating.

According to Taylor (1975), creativity for engineers includes the ability to develop a new use of old parts and new ways of seeing old things in an ingenious manner. What emerged through this experience was a revised understanding of an internalized value for creative problem solving:

> I've always considered that everything I was learning was defined by the point value of the assignment. This approach was very different than what I have experienced in my engineering background. Now I might look at an engineering project with more of a goal in mind rather than just to get it done.

Many of the other engineering students shared similar responses, indicating that with future assignments they would consider exploring alternative directions in process and eventual outcome. It was clear that experience with open-ended creative options enabled an alternative conception beyond efficiency when problem solving. Creativity in engineering is the ability to formulate innovative departures from established principles of thought, to *think outside the box*, to move beyond the current thinking of engineering and, over time, develop a new way of creating and designing:

> I really learned that this type of creative process takes time. We talk in engineering about a flash point, when things just come together, but I never considered how much time it would take. There is a lot to learn before I will be useful in industry. With this type of creativity, I will have a lot of fun learning.

Developing Communication Skills Through Interdisciplinary Collaboration

An additional and equally important learning outcome that emerged from this interdisciplinary collaboration was an expansion of students' communication skills. As with many disciplines, both engineering and music have extremely focused curricula that require an abundance of time working with disciplinary colleagues. Interdisciplinary collaboration is a means to help students widen their perspectives, explore relationships among subjects, and build critical and analytical thinking skills while interacting with students from a broad range of academic areas.

Interestingly, students recognized an importance of communication skills as an essential development needed for success in their discipline:

> I am excited to be working together with someone from a different area because this is something that we will have to do out in the industry. We will have to work with and communicate ideas to people who don't have our education or background. I know I will have to help my clients understand what we as engineers are doing and talk in terms that they will understand. So I guess I am excited to broaden my horizons and try to get an experience on how to do that now before I do it in the industry.

The engineering students indicated they understood the importance of clear communication when interacting with those that possess different levels of understanding. One engineer described this as communicating with the end user: "It's easy to put specs on a piece of paper, but it is equally important to communicate the plans with those who will be the end user. If I can figure out and accommodate their needs, and inversely, learn what I need from them, then I can be successful." Another engineer eloquently described a recognition of need for enhancing communication skills:

> I am used to working with engineers and even share an apartment with engineers, so working with someone whose background is different is a very good experience and will be useful to me. There is a bad stereotype that engineers don't know how to communicate with anybody, and it's partly true. We get bogged down in technical classes and develop advanced knowledge of our field that we find it difficult to step back and communicate ideas on an appropriate level. I have been told many times that, as an engineer, I will need to be able to communicate my ideas. I will be much more valuable if they won't have to hire someone to mediate between me and a client. But communication goes both ways. I will have to understand about others' fields as well. Learning about other disciplines is important so I can talk about things without sounding like an idiot.

Although the desire for control initially hindered both collaborative creativity and a desire to interact in decisions, students experienced unconsidered options resulting from opening oneself to another's ideas. Following this recognition, students learned to adjust disciplinary language with consideration of the other's understanding. Enhanced communication skills emerged as an important developed skill.

Enlightenment Through Teamwork

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By the time they leave college, chances are most engineering graduates will have participated in many different kinds of teams. They may have participated in teams centered around athletic programs, music and drama productions, fraternity and sorority club activities, or laboratory and academic projects. Even in engineering programs, multiple team experiences are commonplace. But it is often a challenge to develop engineering experiences that include cross-disciplinary teamwork in ways that reflect authentic expectations in the field. “To be successful in today’s workplace, engineering and computer science students must possess high levels of teamwork skills. Unfortunately, most engineering programs provide little or no specific instruction in this area” (Lingard, 2010, p. 34). Contributing to this challenge in engineering, instructors may have had little or no experience operating in teams; likewise, they may not be familiar with effective approaches to teaching and assessing teamwork (Lingard & Barkataki, 2011).

In the collaboration, the engineers and the musicians described their experiences working as a team: “Working with another person on the project was a way to get different ideas, like two heads are better than one. It also allowed for each of us to go in independent directions and never get anywhere.” Most of the engineering students described that they were not used to collaborating. Making decisions independently had been the norm: “It was a little difficult for me because I like to have control, but my musician colleague’s ideas were better than mine. As far as the compositional aspect, he has a level of knowledge and skill that I can’t match. I had to learn to trust him a little bit. It forced me to let go a bit.”

In all instances, the students described ways in which they maximized each other’s knowledge, talents, and capabilities to reach goals in the creative process. Both music and engineering students described collaborative decision-making either by trusting in another’s ideas or by generating a new ideas from the other’s thoughts: “Working together was awesome. My engineering colleague had a basic song ready to go, so together we were able to use the form from his piece and build upon that.” Each made a contribution to the final product in a variety of creative ways.

It was common for the team partners to show their appreciation for each other’s contributions, often humbly diminishing their own impact on the final product:

> Our composition sounded really good. We, the engineers, had a say on the sounds we created and how they were put together. Both of us worked with tweaking the sounds and our musician partner put the musical touches to it. We learned to communicate our knowledge of the technology together we could manipulate the programs and allow us to fulfill the vision.

Their musical colleague, interviewed at a different time, identified the engineers’ contributions as foundational in the development of the composition enabling him to be able to create the musical components through their capabilities of working the technology: “I wouldn’t have been able to achieve the final product as it turned out without their help. We did this together with equal input.” It was clear that contributions in areas where the other felt less confident was perceived as among the most powerful learning that occurred as a result of the experience. Individuals from both groups learned to rely on the strengths of the other. The students learned to recognize and respect skill-sets of other team members, and experienced a creative problem-solving process in ways they hadn’t previously considered: “The most important thing I learned came through the collaboration, working with another person in a very different context. I think the most important thing I got out of the experience is working with another person.”

Conclusions

The varied processes of creative problem-solving involved in each discipline brought an awareness of possibilities to the students:

> What I learned was to take a wider view of a problem. I usually follow set directions, but as the project evolved, my consideration of how to progress was expanded beyond what I typically could have come up with. I guess when working with others, ideas that are outside of the typical sequence or different than mine are useful.

Students discovered options for creative problem-solving that included the following: (a) pursuing options beyond a normal framework or structure within their discipline, (i.e. considering creative alternatives that might generate an improved outcome); (b) deliberation of notions beyond their own that influenced the direction of the problem-solving process; and (c) recognition that effective communication requires consideration of another’s beliefs, understandings and intentions, as well as flexibility within these considerations. When students re-conceptualize what they know and can do, then the opportunity for growth becomes substantial as supported by the theories of cognitive dissonance described by Festinger (1962) and Motschnig & Nykl, 2003. The point when students looked differently upon their own discipline was after they completed the collaborative assignments.

Of equal importance through this cross-curricular experience was exposure to another discipline. The students discovered aspects about their own understandings that resulted in alternative considerations. Many described the experience as an expansion of their disciplinary framework. Interdisciplinary collaborative teamwork should be encouraged in order to bring together a diversity of expertise needed to motivate divergent thinking, openness, flexibility of one's own convictions and willingness to take risks (Cropley & Cropley, 2000).

In short, engineers need a creative mind to meet the advancing expectations in the engineering profession, which may include the design of new products or systems and improvement existing ones. Creative engineers should be willing to pursue and explore information beyond their current understanding and generate novel solutions to engineering problems or in the production of a unique product (Guilford, 1967). One major component of creativity is divergent thinking, which involves producing new and possibly multiple solutions. It is measured by the ability to generate many responses or ideas, the ability to generate varied ideas from new perspectives, take risks of identifying and rationalizing the novelty, and turn generated ideas into innovative products. In contrast, convergent thinking in engineering centers on deriving the single best solution or answer to a given problem. Expanding engineering students beyond convergent thinking to unlock the variability of creativity improves the quality of ideas (Cropley, 1999).

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