Enhancing Creative Strengths in Engineering Technology Students Through Curriculum and Pedagogy Modification

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Abstract

The paper addresses an early investigation of how engineering and engineering technology students develop and communicate novel, relevant, and creative ideas in selected coursework. A specific goal is to trace how this creative thinking process manifests in their senior design projects, the capstone of the student’s educational experience as well as the first step into their careers. The extent to which engineering students’ creativity is enhanced as they proceed through creativity infused pedagogy in their electrical and computer engineering (ECE) and engineering technology (ET) courses is assessed. In addition, results of the interaction between learning and instruction as a function of the creativity infused curriculum and pedagogy of ECE and ET faculty and their students as displayed in senior design projects will be evaluated. Specifically, how do the instructors modify their instructional approaches to facilitate creative thinking and behavior in students and in turn, how do engineering students’ creative strengths enhance the quality of their senior design projects.

Project Description & Goals

To address the current demand for creative students, this project aims to assist electrical and computer engineering and engineering technology students and faculty in building a strong and confident orientation towards generating and implementing new ideas in engineering and engineering technology courses related to successful outcomes. Through a new interdisciplinary research collaboration between faculty in engineering, engineering technology, psychology and education, we plan to address the need for understanding how engineering students develop ways of deriving novel ideas and communicating these ideas in the context of the classroom and trace how their creativity manifests in their senior design projects. The goal of this project is to study the extent to which engineering and engineering technology students’ creativity is enhanced as they proceed through electrical and computer engineering (ECE) and engineering technology (ET) programs, how ECE and ET faculty modify their instructional approaches to facilitate creative thinking and behavior demonstrated in students and in turn, how engineering students’ creative strengths enhance the quality of their senior design projects.

This two-year pilot study will assess the development of the creative abilities of approximately 70 electrical and computer engineering and engineering technology students as they progress from junior to senior years in their respective programs. Two measures will be administered to all the students: the Reisman Diagnostic Creativity Assessment (RDCA) will be given to students before and after their courses (some of which will embed faculty creativity training) and the Torrance Tests for Creative Thinking (TTCT) will be given to a random sample of these students as a measure of concurrent validity. To complement these creativity assessments, a smaller sample of approximately 15 engineering technology students will take an Experience
Sampling Methodology (ESM) Mobile App Survey reporting their mood states while completing creative problem solving tasks in the classroom. This survey will help pinpoint students’ levels of positive and negative mood, intrinsic motivation, self-efficacy [perceived ability], and cognitive engagement with the type of engineering task. The students will use iTouch and iPhone devices to take the ESM Mobile App Survey. Each student will take approximately five surveys a week for 20 weeks over the course of two years, generating possibly 1500 responses, which can be viewed by faculty in real-time. In the ECES study, we will participate as instructors of the ECEE 304, ECES 352 and ET courses MHT 314, MHT 401, and MHT 421-423. Based on the students’ TTCT, RDCA scores and ESM Mobile App Survey Responses, the instructors will receive training conducted by the project evaluator to enhance certain areas of creative thinking and behavior in their students, such as fluency and flexibility in thinking. As a result of the training and development, and the data collection and analysis, it is anticipated that faculty will make positive changes in their pedagogy, report on the development of student creativity, and disseminate new curriculum to other engineering and education faculty and students at Drexel University and other universities through websites, presentations and publications.

Research Questions

The project explores the relationship between engineering students’ creativity, instructional design embedding creativity, and final student projects as they progress from junior to senior years. In particular we want to know:
1. How do surveys and measures delivered via mobile application technology capture the time-sensitive, developmental nature of student creativity?
2. How do levels of student creativity change before, during and after creativity-based instruction?
3. How do these measures correlate to senior projects as judged by an expert panel of engineers?
4. How do faculty incorporate creativity into their engineering curriculum and pedagogy?

Motivation for Embedding Creativity into Engineering Education

Politicians, professors and seminal educational policy initiatives emphasize the strategic importance of fostering creativity and innovation (C&I) in students and in the workforce (see Bronson and Merryman, 2010; IBM, 2010; Obama, 2009a, 2009b, 2009c) yet a deficit in this area persists. C&I must be engendered in our students if the United States is to remain competitive in the new global economy. According to professor John M. Eger (2011):

As a whole new economy based upon creativity and innovation emerges – the dawn of the “Creative Age”— the importance of reinventing our business strategies, our corporations, our communities, our schools and more is critical... We desperately need to redesign our high school and college curricula in particular, to focus on preparing students for this new competition.

While the mandate of adding C&I as an enrichment to student learning should be part of the mission of any institution, few institutions embed C&I into their curriculum or assess how well C&I is enhanced in the lives of their students as they proceed through their programs. To address this need, a newly initiated research collaboration between the College of Engineering, Goodwin
College’s Engineering Technology and Educational Leadership Programs and the Torrance Center for Creativity and Innovation at Drexel University has been formed around the Research Initiation Grant project proposal aimed at studying the outcomes of creativity assessment using mobile application technology embedded into selected engineering and engineering technology courses. It is hoped that this collaboration will engender findings that will sustain larger research projects on embedding creativity into engineering education at Drexel and beyond.

**Addressing a Lack of Student and Faculty Creativity**

From an instructional and career-based standpoint, creativity can be a valuable asset for an engineer. A creative engineering student demonstrates mastery in his or her subject area, thinks in new and useful ways, and finds and solves problems. These abilities are implied in the University of Georgia’s profile of engineers, which emphasizes technical excellence, humanism and innovation as the foundation for developing an Interdisciplinary Design Studio course, funded by NSF’s Course, Curriculum, Laboratory and Instruction grant (Constantino, Kellam, Cramond, Crowder, 2010, p.2). In addition, these skills are referenced in both mathematics and science standards (American Association for the Advancement of Science, 1993; National Council of Teachers of Mathematics, 2000; National Research Council, 1996), and Standards for Success (Conley, 2003). Program outcome 3d in the Technology Accreditation Commission (TAC) of the Accreditation Board for Engineering and Technology (ABET) (2009, p.2) requires that students be able to demonstrate the “ability to apply creativity in the design of systems, components, or processes appropriate to program objectives.” Despite this belief, there is a lack of research incorporating cutting edge educational and psychological research on measuring creativity into engineering education. We therefore propose this Research Initiation Grant to fill this gap through the collective efforts of faculty in engineering, engineering technology, education and educational psychology using mobile technology to collect student feedback as they move about the classroom and complete homework tasks.

The exploratory pilot study aims to generate insight into the development of engineering and engineering technology students’ creativity according to data collected through measures delivered on mobile devices such as iTouches/iPhones/iPads as well as examining how to improve meaningfully engineering/engineering technology curriculum and pedagogy. Both students and faculty members will learn (and then practice) ways of recognizing creative thought and behavior in his or herself (at the intrapersonal level) and within others (at the interpersonal level). We adopt the stance that creativity tends to be beneficial when it is relevant to a domain e.g., engineering, rooted in the mastery of basic engineering principles. By making engineering faculty aware of possible challenging behaviors of creative students, faculty will have the potential to view such student behavior in a different way and adjust their pedagogy resulting in win-win student-teacher relations and increased opportunities for the student to achieve in the classroom. Creative students may display challenging behaviors including dislike of routine type learning, are day dreamers, and are early pinpointed by teachers as trouble makers and poor students (Goertzel, 2007). On the other hand, creative students are self-directed learners and persist in tasks that interest them. Most creative people learn that there is a time to conform and a time to be creative. The key may lie in cultivating patience and understanding, founded on the knowledge that such creative traits are common among people who are naturally independent, unconventional, and bored by trivialities (Davis, 1993). Because rigid enforcement of rules will
alienate creative students and squelch their creativeness, flexibility and understanding are necessary; creativity needs a facilitative environment, not an authoritarian one (Mann, 2009).

To engender a facilitative environment that fosters engineering student’s creativity, role-playing will be used to train faculty members and they in turn will incorporate role play as a pedagogy. In role-plays, students practice exploring abstract engineering problems in various scenarios, thus resulting in teamwork that is more concrete, real and spontaneous. Role- play allows for immediate feedback from peers and instructors, facilitates the expression of attitudes and feelings, and provides opportunities for students to speculate on uncertainties. The role-play activities will be researched-based (Katz-Buonincontro, in press; 2008, 2010) with a focus on barriers and remedies for infusing creativity into the learning process, as well as engineering career options. It is expected that this creative- and innovative-focused pedagogy will result in enhancing faculty members’ own creative strengths and their students’ creative strengths leading to improved student academic performance, self-efficacy and engagement.

Creativity is a higher order thinking skill demanding considerable depth of content knowledge as well as novel, or original thinking that is also useful, or practical for success in academics and in life (Sternberg, 2003; Sternberg, Jarvin, & Grigorenko, 2009; Sternberg, Kaufman, & Pretz, 2001). Yet, engineering students may not be comfortable with or be aware of creative thinking strategies. In order to engage in creative thinking and problem solving in subjects like engineering, students must build a strong and confident orientation towards learning (Standards for Success, 2003, p. 31). From an instructional standpoint, students may experience anxiety in mathematics and science tasks. In turn, we hypothesize that this anxiety may be connected to low confidence, especially for female engineering students who do not pursue enrolling in engineering courses or, once enrolled, drop out of engineering courses. As Milgram (2011) has indicated, “self confidence is a predictor of success for women and girls in technology courses.” Therefore, we take a careful and critical approach to researching creativity as a developmental process (Beghetto and Kaufman, 2007) that may be enhanced by working in groups (Sawyer, 2003) but may differ for students depending on gender and self-efficacy (one’s belief in his or her own ability). This approach ultimately necessitates both developmental and diagnostic measures of creativity developed in education/educational psychology and applied to engineering.

Past research on creativity in engineering and architecture students has focused on techniques such as grading and journaling (Betz, 2009), special tests (Matthews & Jahanian, 1999), rubrics (Mitchell, 1998), drawing tests (Cropley & Cropley, 2000), and even creative engineering design assessments (Charyton & Merrill, 2009). However, to more closely examine the fine-grained developmental features of learning creativity, this project focuses on the use of complementary validated measures of creative thinking and problem solving: the RDCA (a diagnostic measure), and the ESM Mobile App Survey, which examines the development of “mini-c creativity” (Beghetto & Kaufman, 2007) as opposed to eminent scientific creativity. These measures will generate insight into the time-sensitive, developmental nature of student creativity as it unfolds. In order for students and faculty to see themselves as creative engineers, it is imperative that they explore and practice how to think and act creatively before their products are ultimately judged as eminent contributions to their fields. Thus, engineering faculty will be trained on facilitating creativity in students—not just measuring students’ creative abilities. To do this, the faculty training will incorporate what we call “creative heuristic diagnostic teaching.” Engineering
faculty in the program will be coached in theories and tools and techniques for enhancing creativity (Reisman & Torrance, 2002, 2000a, 2000b; Reisman et al, 2002; Reisman, 1990; Borko & Putnam, 1995; Little, 1993; Miller, Lord, & Dorney, 1994; NFIE, 1996; Tillema & Imants, 1995; U.S. Department of Education, 2000; Whitelaw, 2004). Project activities are designed to increase the instructors’ motivation and commitment to help students learn (Hodges, 1996); affirm their strengths and enhance their sense of efficacy; empower them to take instructional risks and to assume new roles and responsibilities; increase the likelihood that what is learned will be meaningful and relevant to particular contexts and problems; improve instruction (Hodges, 1996); and make the classroom culture more collaborative and improvement-oriented.

**Project Outcomes**

1. RDCA student scores will increase by selected factors.
2. RDCA professor scores will increase by selected factors.
3. Professors will state awareness of student creative strengths during end of year debriefing session.
4. The results of the ESM Mobile App Survey will show students’ self-reported levels of emotional responses, intrinsic motivation, self-efficacy, and cognitive engagement as they correlate to real-time engineering tasks in the classroom.
5. The ESM Mobile App Survey results will show positively accelerated curves in the development of awareness of creative strengths.
6. Retention of women and minorities will be greater than in previous classes of engineering and engineering technology students.
7. Senior design projects meet specified creative and innovative criteria.

**Research Design**

Mixed methods (quantitative and qualitative methodologies) will be used to study and evaluate the enhancement of creativity in engineering students and professors (Creswell, 2003). This mixed research methods approach will generate an understanding about both the process and products of creative thought and behavior in the context of engineering education (Borrego, Douglas & Amelink, 2009). This research design will enable us to answer the research questions, “How do surveys and measures utilizing mobile application technology capture the time-sensitive, developmental nature of student creativity?” “How do levels of student creativity change before, during and after creativity-based instruction?”, “How do these measures correlate to senior design projects as judged by an expert panel of engineers?” And, lastly, “How do faculty incorporate creativity into their engineering curriculum and pedagogy?” Effective intervention methods to enhance creativity are available with the RDCA, and others will be developed in collaboration with faculty, and applied in situations where there is a negative or no appreciable change in the creativity measurement. Experience Sampling Methodology [ESM] will be conducted under the direction of one of the faculty. An ESM survey instrument will be tailored to the unique learning needs of engineering students. ESM is a method for documenting individuals’ experience several times a day through self-report surveys, and has been applied to a variety of educational and organizational research issues. This approach was originally developed by psychologist Mihaly Csikszentmihalyi to study flow and creativity (Hektner,
Qualitative focus groups will be conducted with groups of seniors to authentically ascertain the challenges to learning creative thinking strategies.

Participants and setting

Two populations comprised of junior and senior students will be given creativity assessments when they enter their junior and senior years, respectively, as well as within selected courses that involve problem solving and engineering design processes (see Table 1). During Year 1, the RDCA will be given to both the juniors and seniors in the following courses: ECEE 304, ECES 352, MHT 314, and MHT 401. The seniors in MHT 401 will be used as a quasi-control group and interventions to increase students’ creativity will be applied, where needed, for the juniors only but not for the seniors in MHT401. In Year 2, the ECE seniors in the project will be tracked, but not in any particular course. They will be given the RDCA at the beginning and end of their senior year. The seniors in MHT 401, MET 421, 422, 423 will be given the RDCA at the beginning, middle and end of the course, but no interventions will be applied. In addition, to help validate the results from the creativity measurements, an expert panel chosen from industry, including members of the ET Industry Advisory Council, will assess the creativity of the ET students’ senior design projects using a “project creativity metric” (Richardson and Reed, 2010).

Project Evaluation

Because this project is pilot and exploratory, it will focus on formative and summative questions that will serve as a means of organizing a Final Report and a Project Outcomes Report to the project staff and other relevant groups. Those reports as well as information provided by the evaluation team to project staff as major data collection activities are completed will be for the purpose of formative evaluation; i.e., evaluation used for assessing progress and informing project modifications/improvements. The questions, stated below are written as formative evaluation questions. The evaluation report developed in year 2 (final year of the project) will be summative in nature, and the evaluation questions will be reframed to reflect the accomplishments, or lack thereof, of the project. An example of this reframing follows:

**Formative Question.** To what extent is the project accomplishing its stated objectives?

**Summative Question.** Did the project accomplish its stated objectives? If not, why not?

The foundational evaluation questions stated below may need adjustment based on discussions among the project staff and evaluation team, or as needed project modifications are identified. At present, the evaluation questions are:

1. To what extent are the stated objectives and outcomes of the project being accomplished?
2. What problems in project implementation have emerged? How have they been resolved?
3. How do stakeholders (students, faculty, project staff, et al.) perceive the project and the activities therein?
4. How is information about the project and its activities being disseminated and to whom?
5. What components of the project appear to be sustainable beyond the pilot period? How?
It is assumed that project staff will be collecting data from faculty and students regarding their problems in courses and their satisfaction with specific activities (e.g., coursework, assignments, etc.) on a regular basis, and that these data will also be available to the evaluator.

The evaluator will issue to the project staff a preliminary report in July of each year. Complete annual evaluation reports will be provided each September. The report completed in September of the final project year will be a summative report addressing the accomplishments and value of the project as a whole. All reports will contain recommendations to the project staff to assist in project improvements and in developing and implementing future projects (summative report). In addition to the annual preliminary and complete reports, the evaluation team will maintain regular contact with the project team, sharing data and information as they become available, which may be useful in modification of project activities.

Summary

A recent survey of 1,500 chief executives conducted by IBM's Institute for Business Value (IBM, 2010) identified "creativity" as the most important leadership competency for corporate success of the future. Note that the desired competency of leaders is “creativity—not operational effectiveness, managerial discipline, influence, or even dedication.” Until recently, creativity was viewed only as an essential element of research or product development, not the crucial characteristic of leadership. This research highlights proposed strategies for infusing creativity into engineering and engineering technology education and tracing how the creative thinking process manifests in the students’ senior design projects. The project also involves assessing the extent to which the students’ creativity is enhanced as they proceed through creativity infused pedagogy in their electrical and computer engineering (ECE) and engineering technology (ET) courses.

References


Biographical Information

DR. ABI AGHAYERE (PI) is Professor and Senior Associate Dean in the School of Technology and Professional Studies, Drexel University with teaching interests in structural engineering and construction management and research interests in engineering education and learning outcomes assessment. A co-author of three structural engineering textbooks and numerous scholarly articles with many years of practical design experience, he was a winner of a university-wide excellence in teaching award in 2005. Dr. Aghayere will be the project manager responsible for budgetary oversight and the preparation and submission of all deliverables.

DR. JEN KATZ-BUONINCONTRO (Co-PI) is Assistant Professor, Educational Leadership in the School of Education, Drexel University has expertise in ESM methodology, qualitative methodology and creativity, leadership and the visual arts. Dr. Katz-Buonincontro teaches leadership development courses and research methodology courses. She received a Drexel University Career Development Award (2010) for leading a project to develop and administer an ESM Mobile App Survey to leaders in the area of mood states and creative problem solving tasks.

DR. VLADIMIR GENIS (Co-PI) is Professor and ET Program Director in Goodwin College and teaches courses in engineering technology and non-destructive evaluation (NDE). His research interests include ultrasound wave propagation and scattering, ultrasound imaging, nondestructive testing, electronic instrumentation, piezoelectric transducers, and engineering education. From 2004 to 2006, he served as a member of the PA Emerging Technologies and Workforce Development Consortium and as a member of the Advisory Board of Drexel Learning Center.

DR. GARY FRIEDMAN (Co-PI) is Professor of Electrical and Computer Engineering at Drexel University with general research area in the application of magnetic and electric discharge phenomena to medicine and biology. Dr. Friedman was a Co-PI on the NSF grant “NIRT: Nanotube-Based Nanofluidic Devices and Fundamental Fluid Studies at the Nanoscale,” Award CBET-0609062, Amount $1,001,999, Period: 7/07-12/08, PI: Y. Gogotsi (Drexel Univ.). He is also a Co-PI on a three-year joint NSF IRES (#0826207) project in Plasma Medicine.

DR. YOUNGMOO E. KIM (Co-PI) is Associate Professor of Electrical and Computer Engineering at Drexel University. His research group, the Music & Entertainment Technology (MET)-lab, focuses on machine listening, music information retrieval, and new interfaces for music. Dr. Kim is currently PI on IIS-0644151: "CAREER: Exploring Creative Expression through Music and Audio Technology” (2007-2012), and is also Co-PI on DGE-0947936: "Catalyzing STEM Education via the NAE Engineering Grand Challenges.”

DR. FREDRICKA REISMAN (Program Evaluator) is an expert in designing assessment and evaluation procedures. She founded and served as the director of the Drexel School of Education. She is director of the Drexel/Torrance Center for Creativity and Innovation, and a professor in the Goodwin College of Professional Studies. She has conducted onsite evaluation of numerous Pennsylvania and New
York State university teacher certification programs. Dr. Reisman has authored/co-authored a number of books in mathematics education and creativity. In 2002, she received the national Creativity Award from the American Creativity Association (ACA) and currently serves as ACA president.