Teaching Innovation Projects

Volume 4 | Issue 1 Article 4

The Dawn of the Creative Age: Fostering Creativity Among Engineering Students

Dipanwita Gangopadhyay
Western University, dgangop@uwo.ca

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Summary
In their professional capacities, engineers identify problems, apply scientific and mathematical approaches to solve these problems, and provide reasoned justifications for their chosen approach. Such responsibilities call for well-developed analytical and creative thinking skills. Traditional engineering education focuses primarily on the development of analytical thinking skills, with students' capacities for creativity being assessed only in the context of capstone projects or not at all: this often neglected aspect of engineering education needs attention. To that end, this workshop explores opportunities and methods for incorporating creativity into engineering pedagogy.

Keywords
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SUMMARY

In their professional capacities, engineers identify problems, apply scientific and mathematical approaches to solve these problems, and provide reasoned justifications for their chosen approach. Such responsibilities call for well-developed analytical and creative thinking skills. Traditional engineering education focuses primarily on the development of analytical thinking skills, with students' capacities for creativity being assessed only in the context of capstone projects or not at all: this often neglected aspect of engineering education needs attention. To that end, this workshop explores opportunities and methods for incorporating creativity into engineering pedagogy.

KEYWORDS: creativity, innovation, engineering education

LEARNING OBJECTIVES

By the end of this workshop, the participants will be able to:

- compare and contrast emerging instructional trends that foster creative thinking with more traditional approaches in engineering education;
- articulate the concept of creativity and identify barriers to integrating creativity into current engineering education systems;
- develop an awareness about various frameworks for creative problem-solving and a number of creativity assessment tools;
- formulate strategies for enhancing the individual and group creativity of engineering students; and
- devise strategies for integrating pertinent creativity-friendly approaches into various engineering contexts.

REFERENCE SUMMARIES

Amoussou, G.-A., Porter, M. & Steinberg, S. (2011). Assessing Creativity Practices in Design. *41st ASEE/IEEE Frontiers in Education Conference,* Oct 12-15, 2011, Rapid City, SD.

This article describes the outcomes of a survey used to determine assess the status of creativity training in computer science and engineering curricula. The results show that creativity training is being adequately addressed in some areas of engineering instruction, particularly in courses that involve interdisciplinarity. The authors note, however, that deliberate strategies to enhance group creativity are largely absent from engineering curricula and since collaboration and team-work are such vital parts of professional engineering, these strategies should be put into practice. The authors have produced a detailed list, and descriptions, of several practices that promote group creative process. The recommendations mainly comprise the following: (i) bringing interdisciplinary learning and interdisciplinary professional behaviour into the classroom; (ii) teaching or encouraging creativity and stressing its importance; (iii) encouraging students to support each other in their explorations of creativity; (iv) expecting students to be creative; (v) rewarding creativity appropriately; (vi) grading appropriately for both basic knowledge and creative projects; (vii) instructing students to avoid rushing to judgements when working through assignments; (viii) continuing to stress goal-setting; (ix) continuing to model creative behavior; (x) maintaining social ties / familiarity among students; (xi) providing constraints on the creative process; (xii) giving students more information about group dynamics and social psychological factors that will help them improve group creativity; (xiii) promoting more diversity in creative work groups; and (xiv) involving faculty in interdisciplinary experimental research with social psychologists.

Felder, R. (1988). Creativity in Engineering Education. *Chemical Engineering Education, 22*(3), 120-125.

Felder, R. (1987). On Creating Creative Engineers. *Engineering Education, 77*(4), 222-227.

Felder, R. (1985). The Generic Quiz: A Device to Stimulate Creativity and Higher-Level Thinking Skills. *Chemical Engineering Education, 19*(4), 176.

Felder emphasizes the importance of recognizing creativity as an essential component of engineering education. Throughout his study, Felder also suggests various strategies faculty can adopt in the classroom to help cultivate the creativity in engineering curricula and students. Felder argues that creating an atmosphere that is hospitable to creativity in the classroom context is the most critical aspect of enhancing creativity among students. He highlights a series of strategies that can be put into place to foster a creativity-friendly classroom environment. They include: (i) encouraging and applauding questioning; (ii) splitting students into small groups for discussion; (iii) refraining from criticizing incorrect solutions; (iv) offering leading questions; (v) not discouraging the imaginative impulses that can sometimes lead to incorrect solutions; and (vi) providing case histories detailing how various kinds of people resolve problematic situations—discussing these case studies can help to dissipate the sense of awe in students when it comes to formulating solutions in creative, independent ways. Finally Felder advises that instructors identify their creatively gifted students and that they appreciate their talents so that all students get encouraged to realize the potential of creativity as an engineering skill.

I have used the work that Felder outlines here as a lecture topic that not only helps participants realize the importance of developing a creativity-friendly atmosphere in the classroom but that also helps participants identify several strategies for achieving greater creative release and output in their own work. Felder's work is an important model for encouraging students to apply critical and creative techniques in classroom settings.

Genco, N., Hölttä-Otto, K., & Seepersaad, C.C. (2010). An experimental investigation of the innovation capabilities of engineering students. *Proceedings of the ASEE Annual Conference and Exposition,* Louisville, KY.

Genco, N., Hölttä-Otto, K., & Seepersaad, C. C. (2012). An experimental investigation of the innovation capabilities of undergraduate engineering students. *Journal of Engineering Education, 101*(1), 60-81.

The first article focuses on a study which measures the creative capacity of mechanical engineering students and compares the results of different sub-groups within this population to isolate the impact of engineering education on their creative abilities. In the concept generation exercise, for example, freshman and senior level students were asked to design a next generation alarm clock. The final result obtained from this study is alarming: freshmen students significantly outperformed seniors in terms of creativity. Another important aspect of this study reveals that the higher score earned by the freshmen students, in the area of creative innovation, did not come at the cost of either the feasibility or quality of their design from a manufacturing perspective. This study implies that students' creative capacity diminishes as they advance in the engineering curriculum. The authors conclude that these results call for a careful assessment of engineering curricula to enhance students' creativity and adaptability throughout their education.

The second article by the same authors describes a study in which both freshmen and senior students received innovation enhancement training and resources. Results again indicated that freshmen students demonstrated more creative, out-of-the-box thinking without sacrificing anything to the quality and technical feasibility of their designs.

I have used these two articles as a case study that lays the motivation for the workshop.

Liu, Z., Schonwetter, D. (2004). Teaching Creativity in Engineering Education*. Int. Journal of Engineering Education, 20*(5), 801-808.

In this study, Schonwetter defines creativity and explains Taylor's hierarchy of creativity which starts with expressive creativity and develops towards technical creativity, inventive creativity, innovative creativity and, at the summit, focuses on emergent creativity. Schonwetter also discusses divergent and convergent modes of thinking and creativity, outlining the creativity process as well as describing, in detail, possible blocks to it. The list involves: (i) fear of the unknown; (ii) fear of failure; (iii) reluctance to exert influence; (iv) frustration avoidance; (v) resource myopia; (vi) being custom-bound; (vii) reluctance to play; (viii) reluctance to let go; (ix) impoverished emotional life; and (x) over-certainty. Schonwetter then recommends Treffinger's creative learning model as a powerful aid for instructors that can help them encourage the cultivation of creativity in engineering courses. The first level of the model is focused on learning skills and explores basic thinking tools, such as: (i) analogical thinking; (ii) brainstorming; (iii) mind mapping; (iv) attribute listing; (v) morphological syntheses; (vi) forced relationships or connections; (vii) idea checklists; and (viii) the function and use of manipulative verbs, etc.. The second level synthesizes learning skills with the practice of a systematic process of problem solving which is followed by the third level that addresses working with real problems. Schonwetter suggests that the success of the CASE (Creativity in Arts, Science and Engineering) project indicates the presence of dormant creative potential in most students and locates the responsibility of creativity ignition in engineering educators. This spark, of course, will not make each student an Edison or Einstein but it will help them be more creative, predictive and, as a consequence, much more successful in their work and professional endeavours.

This article has served as a foundation for this workshop's organization of how to discuss the definition of creativity and how to identify the obstacles involved in including creativity in Engineering Education.

Zappe, S., Mena, I. & Litzinger, T. (2013). Creativity is Not a Purple Dragon. OPEN 2013, *NCIIA's 17th Annual Conference,* March, Washington, DC.

Zappe, S., Litzinger, T. & Hunter, S. (2012). Integrating the Creative Process into Engineering Courses: Description and Assessment of a Faculty Workshop. *Paper presented at the Annual Conference of the American Society for Engineering Education,* San Antonio, TX.

Zappe et al. provide a consolidated list of implicit and explicit definitions of creativity found in recently published literature, especially focusing on journals in the area of engineering education. The main contribution of this study, however, falls into three main categories. First, the authors have identified the hurdles involving the incorporation of creativity into engineering curricula which they identify as being: (i) the myths related to the constructed nature of creativity; (ii) the lack of ambiguity and opportunities for failure in courses; (iii) the rewards structure shaping most courses; (iv) the difficulty involved in assessing creative behaviors; and (v) the perceptions of students regarding instructors' valuing of creative behavior. Following examining these hurdles, the authors explored the conceptualization of creativity in the research pertaining to engineering education. They found the publications to be less numerous and mostly concerned with creativity in relation to problem solving. Finally, they examined the workshop that they conducted for faculty which focused on the goal of integrating creativity into engineering curricula. For this workshop, they based many of their activities and discussions upon the idea of the creative process as outlined by Mumford and affiliate scholars, instead of banking on the fuzzy notion of "creativity" as a general concept. Mumford's model of identifying and implementing the creative process involves eight stages: (i) establishing the problem of definition; (ii) ensuring information gathering; (iii) developing a concept selection; (iv) forming conceptual combinations; (v) promoting idea generation; (vi) undertaking idea evaluation; (vii) putting forth implementation planning; and (viii) monitoring. A more detailed description of the workshop is presented in the second paper, listed above, which also provides various ideas generated by the participant faculty members during the brainstorming sessions of the workshop. The authors indicate that the success of the workshop lies in embracing a more formal approach to involving creative processes in course curricula. I have adopted Mumford's model discussed in the first paper as a topic of small group activity for this workshop. I have also used this paper as a resource / guide for defining creativity since it contains a detailed list of creativity definitions published in recent literature. Moreover, I have used this paper as the outline of this workshop's discussion concerning recognizing the hurdles involved in creativity infusion in engineering education.

CONTENT AND ORGANIZATION

Duration (min.)	Subject	Activity	Purpose
10	Workshop Motivation	As an icebreaker, participants should be asked to chat with their neighbour about the following prompt: "*In professional engineering contexts, can you offer specific examples in which creative thinking is an essential skill*?". After a couple of minutes, a few volunteers can offer up their responses to the larger group. The facilitator will then briefly introduce the motivation for the workshop and the intended learning outcomes. Focus on the professional and pedagogical importance of embedding creativity into engineering education (see Aghayere, 2012).	This activity will serve to break the ice and get participants talking from the outset of the workshop. Clarifying the outcomes will give participants a concrete sense of what they will gain from actively participating in this session.
10	Investigation of the Creative Capabilities of Engineering Students	The facilitator will briefly describe the premise and methodology of the Genco 2010 experiment. In their 'introduction' pairs, participants will be asked to predict the outcome of the experiment. The facilitator will then reveal the actual outcomes, introducing the notion that traditional approaches to engineering education may be stifling the creative capacity of students.	This analysis of the Genco research will offer additional motivation for the session grounded in student learning outcomes. It will also introduce participants to a method for assessing creativity. This will be important in a later stage of the workshop when participants will be asked to discuss ways of implementing similar creativity measures in various classroom contexts.

25	Creativity: Definitions and barriers in engineering education	Based on Liu (2004) and Zappe (2012, 2013), the facilitator will offer some definitions of creativity for the participants to consider. They will also provide a summary of the key 'barriers' to creativity identified in the resources above. In groups of 4-5, participants will be assigned 1 to 3 of the identified barriers (depending on the number of groups), and will be given 10 minutes to discuss examples of such barriers with reference to their personal experiences as undergraduate students in specific courses (anonymized if necessary). Responses should be collected on chart paper and posted in the room. Each group will be asked to briefly describe ONE example of a barrier as experienced in the real world AND a suggestion for how that barrier could have been overcome by a change in pedagogical or assessment approach.	The participants will be able to identify strengths and weaknesses of their local engineering curriculum with relationship to the development of creative problem solving approaches.
30	Overcoming Barriers: Fostering a creativity-friendly atmosphere in your engineering classroom	Transitioning from the last activity, the facilitator will highlight key characteristics from the suggestions for overcoming barriers developed by the groups and relate those to the creativity-inspiring exercises and atmosphere described in Felder (1987, 1988). The facilitator will discuss specific assignments and classroom norms that can	Participants will be able to translate the general tips for enhancing creativity in engineering to their personal teaching contexts. They will share these ideas with a small group of colleagues, helping to spark further insights.

		support creativity among engineering students. Participants will then be 5-8 minutes, on their own, to complete Appendix A, keeping a specific course in mind. The more detailed participants can be in the description of their intended exercises/atmosphere, the more likely it is that they may translate these ideas into practice. Participants will then have several minutes to share their reflections within their small group.	
10	Creativity Assessment using CEDA, PCT	The facilitator will describe a number of creativity assessment tools that are available, both for creativity in general (CT, CPS, CRT) and for creativity pertaining to engineering (CEDA) based on Charyton (2009). Samples of these creativity assessments can be available in handout format or online if desirable.	Participants will be introduced to tools that can help them measure the impact of the pedagogical changes they conceived of in the previous activity.
5	Revisiting Creativity in Engineering Education and Seminar Feedback	Facilitator will ask participants to volunteer responses to the following prompt: "What was the most important insight that you are taking away from this workshop?" In this way, participants will offer a summary of key learnings. The facilitator can fill in any gaps that they perceive to be important.	The brief summary will help participants to recall what they have learned during the course of the workshop. Note: Be sure to thank the participants for their contributions to the workshop!
Total Time: 90 minutes			

PRESENTATION STRATEGIES

There are various lectures and small group activities incorporated into the workshop's structure so as to allow participants the chance to comprehend various aspects of the theoretical and practical elements involved in being creative and teaching creativity. Active learning techniques have been employed throughout this workshop so as to model for participants collaborative, creativity-friendly activities that promote the development of multiple, viable solutions to a given problem or question. I hope, as a direct consequence of this workshop, that participants will incorporate creativity building interventions into their curricula in specific and measureable ways.

ADDITIONAL REFERENCES

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LIST OF APPENDICES
Appendix A: Creativity Exercises and Creativity-Friendly Atmosphere

Appendix A:

Creativity Exercises and Creativity-Friendly Atmosphere (based on Felder (1988))

Task: In your small group, discuss various ways in which one could exercise creativity and foster a safe atmosphere for student questioning and idea generation in your specific classroom context(s). Please jot down your ideas in the space provided below as you will be asked to explain your ideas to colleagues.

Creativity Exercises:

Strategies to develop a creativity friendly atmosphere in the class: