TEACHING TEACHERS TO TEACH CREATIVITY IN AN ENGINEEERING CONTEXT

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Abstract – This paper discusses diverse approaches to teaching creativity in the engineering classroom. The research methodology has yet to be determined in detail, but the plan is simple: find out what others are doing in their classrooms and report back to them and interested others. The motivation for this presentation comes from the considerable interest our engineering faculty has in developing student creativity, matched, I believe, by a like-minded interest shared in many other disciplines. Research that supports this initiative comes from different fields, but chiefly the field of psychology.

Keywords: creativity, engineering, education

1. INTRODUCTION

This paper outlines the first stages of a research project that aims to explore diverse approaches to learning and teaching creativity in the engineering classroom, particularly in capstone design courses. The goal for the research is to determine the types and levels of creativity skills our engineering students are graduating with and to document how my colleagues are fostering student creativity in courses that prepare these students for the capstones. I will report on this both for distribution to instructors interested in developing creative activity in their classrooms and for use at the Faculty level in assessing and building curricula that meet the criteria of the Canadian Engineering Accreditation Board (CEAB).

Scholarship that supports this research comes from different fields, including engineering and science. Experts in engineering design, such as George Dieter, provide detailed advice on creativity, particularly at the stage of concept generation [3]. Others, such as Jay Brockman, explore engineering creativity and problem solving through reference to Bloom's taxonomy of learning, particularly in relation to the relatively complex activity of knowledge synthesis [2]. Finally, Susan McCahan, providing advice to first-year students, focuses on how creativity can be developed by student teams, using techniques such as structured brainstorming and SCAMPER [5]. In addition to these specialists, aiming to train young engineers and scientists, populists, such as David Jones, are showing TV audiences and readers of the *Guardian* that science has exciting opportunities for "creative types" and is no longer a field defined by rationality and logic alone [4].

The most advanced research into creativity, however, has been coming from the field of psychology, in which scholars are studying not only how creativity is best learned and taught but also how it is stimulated and developed as a transferrable skill. Though psychologists are conducting this research in many disciplines and fields, a notable group has aimed at creative activity in science and engineering. Some researchers, such as Herbert A. Simon, emphasize the role that logical problem-solving plays in the creative process [8], while others, such as Sarnoff Mednick and Dean Keith Simonton, emphasize less rational forces, such as chance, associative thinking, and the powers of the subconscious and the unconscious [6, 9].

The current high level of interest in creativity makes arriving at a satisfactory definition for the term increasingly difficult. The scholars and experts shape and reshape creativity to suit their purposes, and popular websites such as mindtools.com review familiar techniques (brainstorming, TRIZ, SCAMPER, Synectics) while previewing newer approaches (Kano Model Analysis, Provocation, Starbursting), making any one definition seem limited. Rather than drawing pieces from these diverse sources. I have taken the Merriam-Webster definition of creativity as a foundation for my research. I do so because it provides a disinterested high-level definition that is free of discipline-specific connotations or bias. Of note, Merriam-Webster explains that creativity produces "something new" and does so through "imaginative skill." In this definition, there is no requirement that this "something" be useful; rather it is novelty and imagination that characterize creative activity. As well, Merriam-Webster claims that "a highly intelligent person may not be very creative," suggesting that IQ and inventiveness are not synonymous.

2. BACKGROUND AND MOTIVATION

My research interest in creativity in engineering education began with an elective course I designed in Fall

2012: APS325: Engineering and Science in the Arts. As reported at CEEA 2014, students in APS325 create original works of art that are connected to science and/or engineering in some manner and present these works of art to their classmates at the end of term. In Fall 2014, to complement this creative activity, I introduced new assignments that required students to track their creative process, both by keeping a journal and by reporting on their progress during the term at preset meetings with me and through group discussion in class, in which each student was responsible for explaining his or her project, including challenges, to classmates who offered feedback. In addition, I had students complete a questionnaire at the beginning of term and the end of term that asked specific questions about their creative process.

These questionnaires revealed that most students had a markedly different understanding of their creative process at the end of term, after completing their works of art. The difference, for most, was that at the beginning of term they expected their creative process to be guided primarily by logic and rational order, but by the end of term they recognized that chance and, in some instances, the unconscious had played a surprisingly decisive role.

The motivation for my current research comes in part from my experiences in ASP325. On one hand, the high level of student creative achievement stimulated my interest, but equally interesting was that most of the APS325 students had little skill in predicting their creative paths. They had great creative abilities but rather limited understanding of how they made it happen.

As well, my motivation comes from the considerable interest our faculty has shown in developing student creativity. Though my conversations have so far been informal, all I have spoken to are interested in contributing to this research project. Finally, this interest in creativity extends far beyond our faculty and is an interest shared by many other disciplines, as my eclectic References attests.

3. METHODOLOGY

The research will initially focus on student experience in capstone design courses in four engineering departments: Civil Engineering, Electrical and Computer Engineering, Mechanical and Industrial Engineering, and Chemical Engineering. Focusing on capstone courses accomplishes two things: first, it ensures a level of consistency, as all courses are culminating, project-based, and "applied," and, secondly, it ensures a strong focus on creative activity, as these courses require students to use creative strategies to successfully complete the courses. Focusing on student experience will help to reveal perceptions and patterns at the user level, so to speak. Rather than starting with faculty expectations, which would emphasize the goals, starting with student experience will reveal the outcomes, what our graduates are taking away.

Though the parameters of the study will evolve, the Graduate Attributes, those skills our students need to be able to demonstrate upon graduation, as defined by the CEAB, will be a starting point. Three of the attributes most clearly connect to creative activity: 1) problem analysis, 2) investigation (including problem definition), and 3) design; and these will provide a common point of reference for those participating in the research. As well, I have chosen a selection of theoretical and practical texts, included in the References section below, that will provide frameworks from which to study and test specific approaches to creative activity.

3.1 Phase One Research

My first step, currently just underway, is to meet with each of the instructors responsible for coordinating the capstone courses and 1) explain my intentions in this research project, and 2) gauge their interest in participating in the project. Before developing a specific methodology for this research, I'd like to learn more from these people about their interests and concerns and determine how I might use these in constructing my approach.

The next step will involve establishing three meetings with capstone students: one at the beginning of term, one in the middle, and one at the end of term. I have already used questionnaires and interviews in APS325, discussed above, and I plan to use these again as "before" and "after" studies to determine how students' understandings of creativity and the creative process evolve from the beginning to the end of a course.

The pre-course questionnaire will be simple, likely asking students to answer three or four general questions that focus on what they know or think they know about creativity and the design process. Possible questions might include the following:

- 1. Everyone has a different understanding of creativity. What is your definition of creativity?
- 2. Identify one past experience that required you to be creative. Was this a positive experience? What did it teach you about your creative process?
- 3. Do you think creativity will be important to your future success? If so, why? If not, why?

The mid-term questionnaire will ask students to reflect back on their pre-course answers and to look ahead as they plan the final stage of their projects:

- 1. Has your definition of creativity changed since the beginning of term? If so, how and why?
- 2. What types of creative activity have been most important so far in the course?
- 3. If you could do anything differently, what would it be?

4. What has been the greatest creative challenge so far?

The post-term questionnaire, at the end of term, will ask students to look back and reflect on their experience in the course and might also ask questions based on readings:

- 1. Did this course give you new insights into your creative process? If so, what types of insights, and how did they affect the success of the project?
- 2. How could this course give you even more insight into your creative process?
- 3. Have you been able to use any of these insights in other situations, either inside or outside your university courses?
- 4. In *Creativity in Science: Chance, Logic, Genius, and Zeitgeist,* Dean Keith Simonton argues that all four of the above provide models for the creative process. Did any of these models play a role in your creative process in the course?

In addition to these three interventions, I plan to organize focus groups with students to learn more about their perspectives on creativity in a guided discussion setting. While questionnaires provide useful data on individual experiences, focus groups often produce richer data, providing insights that only shared observation and comparison can provide.

3.2 Phase Two Research

In the second phase of the research, I plan to shift my focus from the student experience to the instructor experience. I will begin by presenting the student questionnaire and focus group findings to the capstone instructors. My objective here is to find points of agreement, i.e., those areas where instructor objectives and students outcomes are aligned, and to find gaps, i.e., those areas where the instructional objectives and the student experience are at odds. When searching for points of agreement and gaps, the Graduate Attributes, as outlined by the CEAB, will serve as a foundation. Additionally, the Global Objectives and Indicators, developed for each attribute by the Graduate Attributes Committee, University of Toronto, will help further define the Graduate Attributes. The attributes, including attendant objectives and indicators, that most directly connect to creative activity are as follows:

- Problem Analysis. This attribute asks students to formulate a plan for solving an engineering problem. The various indicators require that students recognize indeterminate and open-ended problems and reframe complex problems.
- Investigation. This attribute depends upon students' ability to "devise" and use "critical analysis" to reach valid conclusions. The indicator that likely requires the greatest creative

activity is problem definition. While aspects of problem definition are often linear and logical, other aspects are often lateral and associative.

• Design. This attribute, directly connected to the previous two, requires students to design solutions for open-ended problems. Students must show that they can frame complex, open-ended problems in engineering terms; they must show that they can generate a diverse set of possible solutions; and they must demonstrate that they are able to select a solution for future development or, in other situations, redevelop or iterate a conceptual design.

The goal at this second phase of the research is to develop a shared set of principles that I can then use to check back through the curriculum in each department to assess the consistency and coordination of instruction in these areas.

3.3 Phase Three Research

In this last phase of the research, I will introduce instructors in lower level courses to the findings from the capstone course research. At this last stage of the project, I will know the areas of agreement between student outcomes and instructor objectives; as well, I will know the areas where gaps exist. Having the instructors teaching introductory courses better understand the path ahead, both for their colleagues and for their students, will give them the opportunity to design curricula that meets the needs of all. Initially, I had considered beginning Phase One at the introductory level rather than the capstone level, but I quickly recognized that creating a consistent and effectively integrated curriculum depends upon a reflective gaze: understanding the destination makes it much easier to design a path leading to it.

4. TIMELINE

I plan to build this project around the fall and winter semesters, beginning in April 2015:

- April August 2015: Meet capstone course coordinators; explain my research plan for capstone courses beginning Fall 2015 and Winter 2016.
- September 2015 April 2016: Collect data from student questionnaires and focus groups. Collect examples of student work for analysis.
- May 2016 August 2016: Analyze the data and report to the Faculty on 1) the findings of the research project, and 2) how we can use these findings to develop a coordinated approach to fostering creative activity, not only in fourth-year capstone design courses but also in courses that prepare students for these culminating capstone courses.

5. CONCLUDING REMARKS

With this research I hope to find a consistent and enriched approach to teaching creativity in our undergraduate engineering classes. By involving both students and instructors in the research, I plan to be as much a listener and a recorder as a speaker and a director. Though I anticipate that we will encourage a degree of diversity in how we approach teaching creativity in different courses and in different departments, a greater sense of community and common purpose can only help us make choices about the types of learning we want to encourage and endorse.

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