Teaching Creativity in Engineering
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Abstract

This literature review examines the teaching of creativity in engineering education. In the fast paced, interconnected world of today, it is important for engineering students to be prepared to meet and overcome the challenges facing society. Engineering curriculum at most universities relies heavily on analysis to aid student understanding but does little to equip future engineers with the problem solving skills they will need. Training engineering students to develop creative solutions may require a shift in the pedagogical approaches taken in engineering classes. Instruction on enhancing creativity and problem based learning are some good first steps. While there may be some difficulties in teaching creativity, it does not need to add burden to an already full course load as creative exercises can be used to encourage deeper student learning.

Background

The National Academy of Engineering initiated a study to develop a vision of engineering and to examine the work of an engineer in 2020. The findings of the first phase of this study which examined how the context of engineering might change in the future were published in 2004. The second phase focused on how to educate the engineer of 2020 and its findings were published in 2005 [1]. The first paragraph of the preface describes the need for rethinking engineering education succinctly. It states:

“The Engineer of 2020 Project centers on an effort to envision the future two decades from now, to use this knowledge in an attempt to predict the roles engineers will play in the future, and to position engineering education in the United States for what lies ahead, rather than waiting for time to pass and then trying to respond. It is driven by concern that engineering students of today may not be appropriately educated to meet the demands that will be placed on the engineer of 2020 and that, without refocusing and reshaping the undergraduate engineering learning experience, America’s
engineering preeminence could be lost. It takes as a given that the nation’s societal goals will not be met absent a robust engineering community in the country. It asks what restructuring of program, reallocation of resources, and refocusing of faculty and professional society time and energy are required so that our educational infrastructure can educate engineers prepared to tackle the challenges of the future. It questions how we can more effectively share with students—current and potential—our passion for designing systems, structures, and devices to solve problems and our conviction that engineering is a profession that offers rich rewards for serving the interests of society.”

This introduction reflects the concern that the U.S. is falling behind other countries in properly educating engineering students. It also highlights the need to connect engineering with the greater good of society in the consciousness of the public. This is important not only to secure funding for engineering projects, research, and instruction but also for attracting intelligent and motivated students to pursue careers in engineering. This key link between engineering and society is often missing and the perception of engineering suffers as a result. The scientific community (i.e. those in subjects like physics, chemistry, and biology) have done quite well in connecting their endeavors to benefiting society. Engineering, on the other hand, has struggled with its image and is often seen merely as “applying science” than providing real breakthroughs that make people’s lives better. The problem solving nature and need for creativity are not appreciated or fully grasped. This misconception exists in the minds of many engineering students and the public.

One of the reasons for this disconnect lies in engineering education. The emphasis in the engineering curriculum on analysis and theoretical understanding is an artifact of a Cold War mentality [2]. While classes on math and science are certainly important, the problem with most universities’ engineering curriculum is that undergraduate classes almost fully consist of the theoretical background of engineering without introducing students to actual engineering design and practice. The first time that many students have an opportunity to do any “real engineering” is in a design project their senior year. Many students find themselves unprepared to create a product to solve a problem as their courses have not effectively equipped them to
move beyond the analysis stage. This may be why one of the recommendations of the Engineer of 2020 Project is to introduce students “to the essence of engineering early in their undergraduate careers” (p. 2).

The following sections will explore this subject in further detail. First, an examination of some of the deficiencies in the engineering curriculum is in order. The second section will explore how creativity and problem based learning can be utilized. The final section discusses a few challenges to teaching creativity in engineering.

**Deficiencies of Current Engineering Education**

University of Illinois professor emeritus David Goldberg is famous for his work in genetic algorithms. His career in engineering education has also given him the opportunity to exam the deficiencies of the current system of educating engineers. In [2], Goldberg notes the mismatch between the needs of the engineering world and the results of engineering education. He describes seven failures of engineering education. The important engineering skills often found to be lacking in engineering graduates are as follows:

1. Asking questions (understanding the problem)
2. Labeling technology and design challenges
3. Modeling problems qualitatively
4. Decomposing design problems
5. Gathering data
6. Visualising solutions and generating ideas
7. Communicating solutions in written and and oral form.

Goldberg argues that these basic skills are missing for a number of reasons but that overall it is the philosophical perspective that is missing. The specifics he notes are that engineering is mistaken for “applied science”, engineering reasoning and epistemology are not articulated,
the content of engineering is assumed to be settled, organization reform is ignored, and the scalability of reform efforts are not adequately addressed.

Other research has described how in typical engineering classes the focus is on teaching content and not on problem solving [3]. Often lecturers or professors spend their time delivering information to students rather than modeling how to develop solutions to problems. The cognitive science surrounding problem solving is also examined in [3] and gives a deeper understanding as to why developing problem solving skills is important.

**Developing Creative Engineers**

A fundamental question that is raised in engineering education discussions is how should engineers be trained? A simple answer might be to provide them the opportunity to do engineering projects. This simple answer may hold a lot of wisdom in it - wisdom that is often forgotten. The projects may be small or simple at the beginning of a student’s career but would grow as their knowledge, skills, and abilities improve. It could be a medium of instruction for fundamental theories and practical skills.

Taking this line of thinking one step further, creativity is important for problem solving and should also be taught. Teaching creativity comes with certain assumptions or questions. What is creativity? Can creativity be taught? How does one assess creativity? How does it impact problem solving? Many of the answers to these questions are contested and open for debate. For the purpose of this discussion, creativity will be defined as 1) the introduction or discovery of new and original ideas and 2) the bringing of something into being. The second definition is especially relevant in engineering. Engineers are in the business of bringing new devices or products into being. It could be argued that the engineering discipline is inherently creative when considering the second definition.

Teaching creativity has been explored by many people, one of whom is Tornkvist [4].
Tornkvist discusses the intentions or reasons people have to be creative. He suggests that people are creative for four main reasons: 1) it is human’s inherent urge to be creative, 2) the source of creativity is human’s struggle for survival, 3) creativity is the solution to the (perceived) world economic crisis, and 4) fame is the motive for creativity, especially in a research context. Tornkvist points out that in reality it is a combination of these reasons at work and not a fixed one for a given situation. He goes on to describe the modes or models of engineering education and makes some recommendations for reforming it. Tornkvist suggests that teachers be able to apply modern educational theory, account for the variety of student learning styles, and utilize more open forms of learning such as problem-based learning. By providing this environment, creativity can be fostered as a lifestyle.

One key component of creativity is divergent thinking. Liu and Schonwetter describe it in [5] as “producing new and possibly multiple solutions or answers or ideas to a problem or question from the available information.” The four main characteristics of divergent thinking are fluency (the ability to generate many ideas or responses), flexibility (the ability to change form or shift perspectives), originality (the ability to generate new and unique ideas), and elaboration (the ability to extend an idea with more details). Divergent thinking differs greatly from the convergent thinking typical in engineering education. When students are given a homework problem set, there is usually one right answer that can be arrived at based on correct analysis of the given information. This implicitly reinforces the notion in engineering students that there is one solution to every problem and that the solution is based on the information provided. In engineering practice, this is certainly not the case. There are numerous possible solutions to any given problem, the information provided to an engineer may not be “complete”, and the problem may need to be reframed in order to be solved in novel manner. This is why divergent thinking should be encouraged and inculcated in engineering education. Of course, convergent thinking also has its place and is a necessary step in the creative process. After generating
possible solutions and elaborating on them, the solutions need to be evaluated in a verification phase so that a final solution is chosen. To be clear, both divergent thinking and convergent thinking are important skills for engineers.

A remaining challenge in teaching creativity in engineering is assessment. How can creativity be objectively measured? In [6], the famous Torrence Test of Creative Thinking (TTCT) is discussed. However, this approach is not feasible in many situations. This may does not need to be a prohibitive roadblock in engineering however. By understanding creativity to include “bring something into being”, a problem based approach can provide some metric. If students are able to meet certain specifications for a desired product (i.e. successfully brought it into being), this could be used to measure creativity to an extent. Hence, even if the originality of ideas may be difficult to concretely ascertain, the creation of a product can be recognized and appropriately rewarded.

Conclusion

Engineering education needs to be reformed in order to meet the challenges facing society. Developing engineers who deeply understand the fundamentals and can creatively solve problems is necessary. The way engineering is taught should be adjusted to not only enable students to conduct thorough analysis but also equip future engineers to develop innovative solutions. Problem-based learning and understanding creativity are tools that can be used by an engineering teacher to reach these desired ends. While there may be remaining questions as to how to best teach or assess creativity, this need not limit its acceptance in the engineering curriculum.
References