Boxed In:
The Lack of Creativity in Engineering Students

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Abstract

The lack of creativity coming from recently graduated engineering students seems to be apparent through my observations of students, standard social stigma, as well as research conducted at the University of Massachusetts, Dartmouth. However, little is known about the reason behind this vastly growing problem. Without a better understanding of the issues, universities will continue to produce engineers lacking innovative abilities and creative motivation. Seven scholarly articles and studies as well as three primary sources were reviewed and analyzed in order to better understand what difficulties universities face within the engineering community. It has come to my realization that not only is the lack-luster curriculum leading to student disengagement, but the professors also have difficulty expressing the value of creativity, as they cannot clearly define what creativity entails in their specific courses and disciplines. Other problems arise when professors who are proficient with the idea of creative teaching are not incorporating it into their classrooms because the courses are material heavy and time-limited. Several solutions such as project-based introductory courses, interdisciplinary study programs, and professor training have been suggested to solve these faults in the engineering curricula. If changes do not begin to occur within the university environment, engineering students may find it difficult to exhibit the main characteristics of a "good" engineer that companies are searching for—becoming an innovator and a thinker.

When discussing the topic of most admirable innovators, names such as Thomas Edison, Albert Einstein, Walt Disney, Bill Gates, and Dean Kamen may come to mind. These great thinkers all had a few characteristics in common. They were astoundingly creative minded and they lacked a formal secondary education. In actuality, Gates and Kamen abused their universities for research resources rather than focusing on the importance of classwork, eventually dropping out. Some of the most notable people in the engineering community found their success outside of the university setting and gained respect for their innovations and creativity. What does this say about the current engineering curricula? Is it stifling students' ability to think independently and be creative innovators? I believe it is.
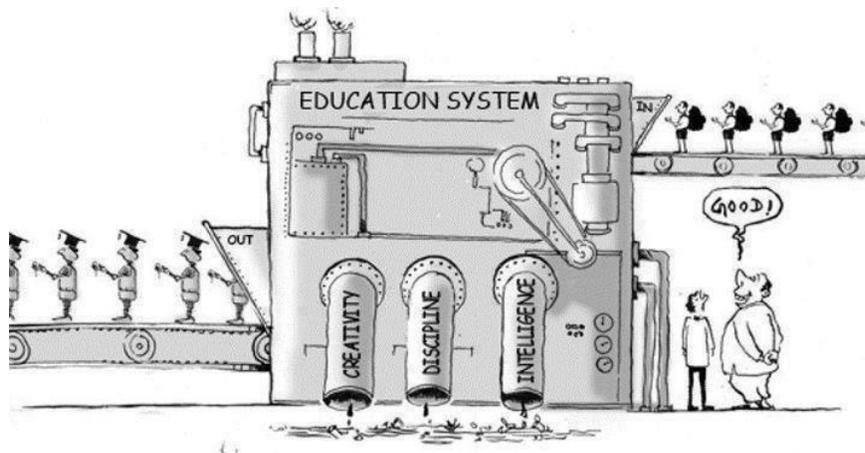

Figure 1. Engineering Memes (2012)

Engineers are considered inventors and thinkers, yet they are also stereotyped as some of the dullest and least creative people to inherit the earth. These two "parts" of an engineer seem contradictory. Yet, both portions hold truth. Engineers are necessary to advance technology whether it is the next music player or a new heart implant needed to save lives. Even with these seemingly creative outputs, engineers can get caught in the rut of design fixation where they can only see what has already been established. Universities should be one of the easiest places for students to acquire the ability to explore and learn. However, when classes become difficult and

time is limited it may become seemingly impossible for students to involve themselves in

research or open-ended discovery. This is why the curriculum must foster these important

aspects of engineering while students are in class. Although creativity is an inherent part of

engineering and current engineering curricula have undergone very little change in the past

decades, the strict knowledge based curriculum seems to be inhibiting the creative outlet and

abilities of students. In turn, graduating engineering students are less creative than their freshman

counterparts.

Many agree that engineers must show creative ability. Liu (2004) states that engineers must

have creative minds in order to solve problems that arise or to design entirely new products. It is

an engineer's job to use previous knowledge and manipulate it into a more efficient or better

design and create entirely new products to solve problems (p. 801). Although creativity is a

necessary part of engineering, it is not incorporated well into many university curricula (p. 801).
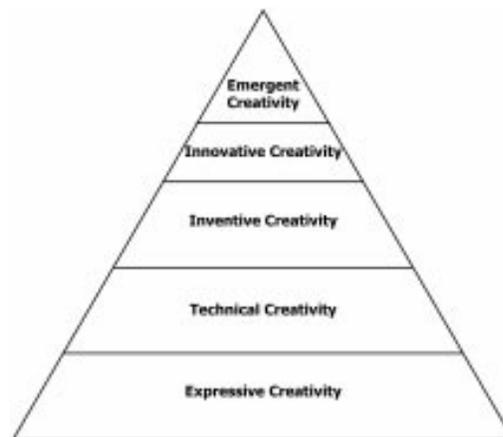

Figure 2. Taylor Hierarchy of Creativity

Based on the Taylor Hierarchy of Creativity in Figure 2. presented by Liu (2004) engineers

should strive for innovative creativity or "think[ing] outside the box" and not following a

standard path (p. 802). However, it appears that most students are graduating with the ability to

reach technical creativity or monkey see, monkey do repetition (repeating a professor's design).

Ahern (2011) claims employers are looking for students who can think critically and does not believe that universities are meeting the requirement well (p. 125). Amoussou (2011) sent 145 surveys to professors in the computer sciences or engineering departments within three California universities. Sixty-one professors replied.. The surveys contained question such as "Is creativity an important component of your field?" and "Do you incorporate interdisciplinary learning in courses?" These questions were answered using a strongly agree to strongly disagree scale (Not applicable was also an option). 96% of professors thought that creativity was a necessary aspect of the engineering curriculum, however also admitted to not knowing the best way to incorporate the subject (p. 2).

There have been attempts to infuse open-mindedness and creativity in engineering curricula across the country such as MIT's Conceive Design Implement Operate curriculum and senior design projects that act as capstones to a student's education. However, there is still a lack of creative encouragement in the university setting. Genco (2012) explains creativity is taught in most classroom settings by exploring various techniques used to formulate new ideas. Among the processes taught are individual brainstorming, brainwriting in which an individual brainstorms on a paper then passes it to the next person at the table in a circle (each person brainstorms off the previous colleague's ideas), 6-3-5 in which 6 people each develop 3 ideas then pass them to the next person for review for 5 minutes, and lastly the C-sketch in which drawings are created and passed on, similar to brainwriting. There are various studies that show the effectiveness of each of these creative procedures. Productivity of group brainstorming is lower than individual brainstorming, but brainwriting creates higher innovation when the designers are exchanging ideas and growing from one another. C-sketching, which incorporates visualization, has shown to be more effective than 6-3-5, which only uses verbal cues. The

usage of these ways of promoting creativity in students is limited by the curriculum due to lack

student interaction in large lectures.

Engineering curricula across the country must meet standards in order to gain accreditation.

Strict guidelines according to ABET or Accreditation Board for Engineering and Technology,

Inc. (2012) include "one year of a combination of college level mathematics and basic sciences",

"one and one-half years of engineering topics, consisting of engineering sciences and

engineering design appropriate to the student's field of study", and "a general education

component that complements the technical content of the curriculum and is consistent with the

program and institution objectives" (p. 4). These requirements greatly limit availability to

explore other subjects or invest in long-term open-ended projects. Yet, schools are held to these

standards in order to be considered competitive. ABET has made very few shifts in their policies

in the past decades, therefore encouraging standard engineering curricula to remain stagnant in

order to receive approval.

The current standards for accreditation are not meeting the needs of engineering students. A

study by Genco (2012) took 94 undergraduate engineering students from the University of

Massachusetts, Dartmouth and put them to the test for three semesters. The independent

variables included the level of student and whether or not "innovation enhancement strategies"

were implemented. The enhancement strategies included introducing students to a new

innovation technique prior to the 6-3-5 method previously mentioned. Those without

enhancement merely knew of the 6-3-5 method. The 48 freshman students were separated into

either "innovation enhanced" or "non-enhancement" groups, and then again into groups of 4-6

(group size was not statically significant to this test). The seniors were similarly divided.

The groups were asked to give ideas for a "next generation of breakthrough alarm clocks." They had 30 minutes to interact with a standard clock and then prompted to use 6-3-5 for idea formation. Those in an "innovation enhanced" group were given additional instructions to only explore the clocks using oven-mitts, blindfolds, and earmuffs. This was encouraged by the Empathetic Experience Design method that suggests a heightened awareness of product occurs when disabling or challenging interactions. The disabling devices were chosen to simulate dark conditions, ear plugs for deep sleep, and mitts to suggest lack of dexterity due to sleepiness or other physical difficulties like "arthritis or unusually large fingers". Genco (2012) believed that understanding certain limitations of present alarm clocks would cause creative influence on the groups handling the item. After 30 minutes with the clocks students were asked to use the 6-3-5 method in silence.

The innovation capabilities of the students were measured using an originality metric and quality metric. The levels of the originality scale included: 0-common, 2.5-somewhat interesting, 5-interesting, 7.5-very interesting, and 10-innovative. Common concepts for alarm clocks were listed and for each concept the students were rated on their originality. The students' concepts were also tested for feasibility with the quality metric: 0-Not technically feasible, 4-feasible but technically difficult for context, 7-feasible, not technically difficult but not existing solution, 10- feasible, not technically difficult and existing solution.

Genco's (2012) study showed that that freshman engineering students at Dartmouth exhibited more originality for ideas than their senior counterparts, but did not lose the technical feasibility of design. Seniors did show higher skills of design details and material choices, which would be taught in higher-level courses. Based on the current curricula for engineering, students are taught the fundamentals, as shown by the seniors, but lose the ability to express them

innovatively. Students are undergoing a tremendous intake of information, and they are doing it

in a way that is limited in time as well as dialogic learning. Johri (2009) says that "[r]eal

learning- that goes beyond fact recollection and memorization— is a dialogic activity that occurs

as students engage with peers and knowledgeable others to construct knowledge while

overcoming conceptual hurdles" (p. 1) His argument is supported by scholars such as Vygotsky,

Bakhtin, Wertsch, and Wells. Chances to converse must be incorporated into the classroom in

order to foster this real learning. Many university courses are limited to 50-150 minutes and each

class time covers a topic that is sped through without sitting and understanding the content.

Homework is completed in much the same manner. Focus groups of college students led by Johri

(2009) have shown that students realize there is a lack of conceptual learning occurring and that

they merely copy what the professor is doing. They admitted that they do not tend to remember

the concepts later on. The students also replied that the courses felt choppy and they had

difficulty piecing together different concepts taught, but rather saw them as separate entities (p.

2). Below is an excerpt from one of Johri's (2009) focus group between two students.

> **Student 1**: You know it still takes stopping and thinking, that's one thing I think we
>
> missed from the class. That chance to stop the process, 'Okay, [what did] we just go
>
> over.'
>
> **Student 2**: Yeah reflect…we don't always get a chance to actually do that in class.
>
> (Johri, 2009, p.2).

Students realize that they go through the motions of learning but do not understand the how

or why behind the knowledge, yet these are important questions to an engineer. Students know

they want a change to the system…that they aren't being taught the material in an appropriate

manner. They just do not know how to start the movement.

Creativity can be perceived in many ways. Haertel (2012) was curious to see how the students perceived creativity and conducted a study at TU Dortmund University. Students replied that "openness", "freedom", "stimulation", "inspiration", and "empowerment" helped to encourage their creativity while hindrances included "pressure, constraints, boredom, and monotony" (p. 4).   Ahern (2011) also examined the different definitions of critical thinking, closely linked to creativity, across several disciplines and whether or not the universities are meeting future employers' requirements in this area. Interviews were conducted among 13 different subject areas including Chemistry, Agricultural Science, Mathematics, Architecture and Civil Engineering, Physics, Mechanical Engineering, Economics, Sociology, Social Justice, Business, History, English, and Law. The purpose of the interviews was to discover how academics defined critical thinking as well as the value of this trait in their discipline. Ahern (2011) asked if there was a discussion or debate about the role of critical thinking and how critical thinking was taught, assessed, and measured in students' work. The interviews also aimed to discover whether critical thinking was addressed implicitly or explicitly in the interviewees discipline and if there were any barriers to critical thinking amongst the students. Each interview was no shorter than an hour.

Because there are several definitions of creativity, it is also proven difficult to explain its context in a class setting. Ahern (2011) discovered that on a broad scale the term critical thinking brought up the same ideas among the interviewees; however a noticeable difference between the ability to describe critical thinking was noted between the non-technical and technical disciplines. Those of a non-technical discipline could easily verbalize what critical thinking was and how they identified it in their students. Those of the technical discipline could not define how they notice if a student is thinking critically but rather responded more along the

lines of "I know it when I see it." This led Ahern (2011) to conclude that it may be difficult for engineering students to grasp the idea of critical thinking and implement it if their professors are unable to verbalize what they mean when using the term (p. 127).

Ahern (2011) was interested to find that the interviewees often admitted that in the first couple of years of engineering curriculum the courses are very content driven leaving little time to introduce critical thinking. This was less of a problem in the humanities (p. 128). This new knowledge concerned Ahern (2011). Employers are readily looking for students with the ability to thinking critically and creatively once graduating from the university (p. 125). Students of the sciences are not being exposed to these necessary concepts but rather taught the material without knowledge how to apply it. It was also pointed out by the interviewees that it is harder to teach critical thinking in large lecture style classes. Problem-based learning or cooperative learning, which typically is used to foster critical thinking, is not possible to implement with a large group of students. Professors who admit to not incorporating creativity into their classrooms say it is due to the mass amounts of information they need to cover and they simply do not have time (Amoussou, 2011, p. 2).

Not only is class time limited but so is the possibility for professors to incorporate open-ended projects into their courses. According to Liu (2004) problem-solving is the most effective way to teach creativity in the classroom (p. 804). It forces students to analyze problems and implement a solution. A common process that has been studied and deemed beneficial includes three steps.

1. Learning and using basic thinking tools such as brainstorming and mind mapping
2. Learning and practicing a systematic process of problem solving which applies the previous techniques to discovering a possible solution (expansion phase)

3.   Working with real problems rather than textbook problems.

This ensures when real obstacles arise student know how to overcome them. The answer is not always simple. It is this final step that students are not experiencing in current engineering courses. Instead they complete homework assignments mechanically where the answer is always clear and certain, only to gain limited understanding and application of the material taught in class.

When the occasional challenge is presented in an engineering course, creativity is limited because students fear failure (Liu, 2004, p. 803). There is tremendous pressure on students to maintain high grades in order to become successful. High grades equate to "do not fail". Students may become uncomfortable with the idea of an open-ended project because they may not succeed in finding an answer. Strict engineering courses focus on mastering the material and performing well on exams. This instills a lack of exploration in students that will translate to their projects. Students may become uncomfortable with open-ended problems, as well as professors because they must determine how to judge creativity subjectively (Amoussou, 2011, p. 4). After a preliminary study of interviewing professors in German universities by Haertel (2012) it was determined that students were asked to think critically, could show commitment towards the courses, and "were trained to create something, to work practically". However, interdisciplinary idea exchange and open discussion was neither required nor encouraged. Students became diligent workers but failed to become creative thinkers due to their "training" in the classroom. Oftentimes, students do not get the chance to choose a topic of interest to them but rather given a list of approved topics created by the professor. Haertel (2012) reasoned that this means the professors are doing much of the creative portion of the work for their students (p.

4). The students merely complete the project in hopes of receiving an exemplary grade on the

assignment.

The need to judge creativity leads to yet another problem inhibiting emergent creativity in

engineering students because there is a lack of consensus on the definition of creativity. In the

interviews by Ahern (2011) professors of technical disciplines could not define how they notice

if a student is thinking critically (p. 127). Ahern (2011) asked the interviewees to provide several

projects or assignments given to the students that they thought forced the students to think

critically as well as examples of students' work. Again it was found that the request for critical

thinking during the assignments was made much clearer in the humanities and was more

apparent in the students' work than in the engineering courses. The engineering students were

not explicitly asked to think critically (p. 128-129). Ahern (2011) found that a good example of a

request for the student to think critically came from one of the Law projects. It clearly told the

student what task needed to be completed, how it should be done, and how concepts and

principles from class should be applied to the situation (p.129). This needs to appear more often

in the engineering courses.

A lack of a definition creates problems in the classroom. Ahern (2011) claims that

engineering professors needs to be able to define what they mean by critical thinking before they

can adequately encourage it from their students (p. 127). Without a solid definition they cannot

possibly teach the necessary skills to develop this trait – a trait that many employers are

searching for. If the professors are not confident in what they mean by creativity the students

will not be either.

There a limited incorporation of creativity in classrooms, and what little is present is often

left to the latter years of education (Ahern, 2011, p. 128). Critical thinking was expressed

explicitly in the very beginning of the curriculum in the humanities according to the responses of interviews. While the engineering disciplines hope to expose their students to critical thinking early on, it was admitted to not be explicitly taught or addressed. It is agreed among the disciplines that critical thinking is a necessary tool; however the interviews proved that many of the engineering students were not being taught or graduated with a solid understanding or ability to implement critical thinking on their own.

Not only is creativity limited in the classroom, but students experience common blocks to thinking outside the box. Amoussou (2011) felt that students should learn about possible factors that inhibit creative thinking in a group such psychological terms of group think and production blocking (p. 4). This would allow students to understand the obstacles they will face and know how to overcome them. Amoussou (2011) presented possible solutions to these creative blocks as seen below.

1) More interdisciplinary learning amongst areas outside of the field of study. This allows students to understand a more typical real-world professional environment.

2) Professors need to be strongly encouraging creativity more verbally to their students and students need to learn to encourage one another to think outside of their comfort zones.

3) According to the Pygmalion effect, professors should expect creativity from their students because when they expect something they are more likely to get it in return.

4) Professors should also reward creativity but not continuously as studies by Teresa Amabile show that excess reward leads to a diminished sense of creativity in the student, because they rely heavily on extrinsic motivation.

5) Professors must remember to grade knowledge and creativity differently. Knowledge

    should be graded purely objectively, but level of creativity is subjective and just because

    the student may fail does not mean they should receive a poor grade.

6) Professors should allow students adequate time to properly develop and idea and not rush

    to judgment.

7) Professors should "continue stress[ing] goal setting" and also seeing creativity as a goal

    itself.

8) Professors need to exhibit creative behavior because students learn by watching.

    According to Shalley &Perry-Smith if the professor is not showing creativity the students

    are more likely to lack creative thinking themselves.

9) A few constraints should be placed because when the creative setting is too open the

    students find a hard time narrowing their ideas and becoming successful in the

    development of an idea (p. 4-5).

 Liu (2004) focuses on the primary blocks for students to achieve high creative thinking and

solutions to each (p. 803). His ideas support Amoussou (2011). The fear of the unknown can be

solved by teaching ways in which students can gather accurate information. The fear of failure

may be overcome by using the mistakes as "teachable moments" rather than being chastised.

Students are interested to understand why it didn't work. The reluctance to exert influence can

be eliminated by recounting tales of scientists who spoke against the masses and stood up for

their designs. Frustration avoidance can lead to students giving up too early in the process. The

remedy is to recall stories of inventors who failed many times (Edison). Resource myopia, or

"failing to see one's strengths and depreciating the importance of resources" is yet another block.

Professors may encourage students to combine each other's strengths. Teachers should

encourage brainstorming for new ideas during class in order to overcome custom-bonding.

Countering frustration avoidance is "reluctance to let go". Allow the student to fail then use as a

learning moment. Encourage celebration when a student overcomes a problem to beat

"impoverished emotional life". Schools may consider competitions that reward creativity. Over-

certainty plagues students' creative minds. Ask the students to evaluate methods and reconsider.

Unfortunately, intelligence is often-time as hindrance in and of itself. Students can perform well

in a controlled setting and will accomplish tasks on time, but real world fluctuation are

unfamiliar and if one lacks a creative mind, difficult to overcome.

This idea that intelligence can be a natural inhibitor was also mentioned by Genco (2012).

Her prior research led her to believe those with low intelligence were rarely creative, but those

that showed high intelligence ranged from low to high creativity (p. 101). It is thought that

people with this higher intelligence may have difficulty shifting their thinking into a creative

mindset, but rather become stuck with what they formally know and understand. Genco (2012)

showed research by Ericsson (1999) and Weisberg (1993) has been done to determine that many

students automatically apply new knowledge to present situations (p. 101). This can have its

drawbacks when what once was, now fails. Students are not sure how to proceed and often get

into a rut of failures. In turn, studies show as a student proceeds through their undergraduate

education they apply more and more of their new knowledge automatically and this leads to

fixation.

Playfulness and environment have profound effects on students' creative output. Liu (2004)

mentions that students often have a "reluctance to play" feeling silly or fear of teasing. Allowing

hands-on learning may battle this. This is a negative aspect of engineering course which are

often quite serious. Idiodi (2012) is in charge of new innovations and development of ideas at

Snagajob. He described the importance of environment. The company wants to sponsor creativity in their employees and fuel a workplace that can foster this. The walls are brightly colored and a slide is in the middle of the office space. Nobody is closed off from their companions in offices and often times meetings are gathered on the floor rather than around a stiff table with business suits. A bar is also in one of the downstairs portions of the building allowing employees to take a break and enjoy one another's company. Idiodi (2012) has felt that this environment, that differs so greatly from the standard, has allowed himself and his employees to feel more open and comfortable sharing their innovative ideas. It allows for a greater sense of community and fosters play in the workplace. People that can interact with each other in an open setting are more likely to bounce ideas and develop a new solution to a problem in the consumer market. Idiodi (2012) feels that play needs to be a bigger focus in order to foster creativity. People need to enjoy their work and feel comfortable spouting their ideas. One person goofing off may lead to a spark in another's mind that could lead to the next greatest innovation. This environment has fostered creativity in adults and is easily applicable to college students.

    A study by Chang (2011) supports Idiodi's (2012) ideas. 690 questionnaires were sent out to high schools in Taiwan and 410 were returned. Of these 388 were considered valid. Chang (2011) ran the statistics of the two portions of the questionnaire, Wu's New Test of Creativity and the author's student survey. It was found that there was statistically significant correlation between "the overall level of class playfulness climate" and the students' levels of creative output. It was noticed by the student surveys that to most students maintaining a relaxed and humorous environment in the classroom was important. It was also observed that many of the classrooms did not embrace a playful environment and that the students were exhibiting less creativity in turn.

Environment is a large factor in the creative output of student. Currently the dull classes that limit student interaction are preventing maximum creativity. Virginia Commonwealth University is hoping to adjust this environment by adding a "Tinker Room" to its engineering facilities in the coming years. Student's will able to explore ideas and play in a relaxed, hands-on environment.

Another possible solution to eliminate design fixation and lack of creativity is interdisciplinary studies. A prominent example of a successful program has been Virginia Commonwealth University's da Vinci Center (n.d.). The da Vinci Center fosters creativity and innovation by interdisciplinary study and research. Students, mostly of engineering, business, and arts, come together to collaborate in product design and advertising. The students go through a core curriculum consisting of a basic seminar as well as classes corresponding to each of the majors. For example, an engineering student would take the Innovation seminar, a specified business course, a specified arts course, and the capstone innovation course in which all three areas work in tandem. Each of the respective majors takes courses in different areas in order to complete the program successfully. The end result is a greater sense of unity among the departments and a highly creative and innovative environment in which students may fully collaborate and develop a sense of self-purpose within a group. The capstone innovation class splits equal parts engineering, arts, and business into several groups. The groups are then allowed to choose one of several problems presented by real-world corporations to solve, develop, and advertise. Many of the solutions provided by students to the companies are considered as final solutions to the company's problem.

Below, the link proceeds to a video about VCU's da Vinci program and how the students deem it valuable.

http://www.youtube.com/watch?v=5cu8NdNz3hE&feature=player_embedded

As a current student of the da Vinci Center, I have already noticed a greater sense of creative development amongst the participating students. They want to become involved in other areas and gain pride in being "well-rounded" in such a unique way. This opportunity also opens engineering students into the world of the arts where they can work hands-on with clay and various mediums. It gives them a break from their standard "sciences only" curriculum and a chance to explore other interests and abilities they may have. Programs such as this are appearing in several schools including Rensselaer Polytechnic Institute in Troy, New York. I feel these types of programs help to foster creativity in engineering student and should be standardly implemented within the university setting and perhaps required within the curriculum rather than the other "standards" of history, psychology, and humanities which rarely interest those of the engineering mind.

The current engineering programs across the country are failing to promote creativity in their students. The classes are often stifling and students do not have time to understand the extent of the material or how to apply it. "Real learning" (Johri, 2009, p. 1) is not occurring and the students are aware of this fact. It is possible for students to explore real-world situations through research and internships but often the heavy course-load prevents students from taking advantage of these opportunities. External learning should still be promoted, but it is the universities responsibility to provide an education and learning experiences within the classroom scheduling.

Many of the suggested solutions are easy to implement in the classroom. However, professors face many obstacles such as large classes, and lack of time. A massive re-working of engineering curricula needs to be administered in order to foster one of the most important traits in an engineer – creativity. Not everything can be solved as easily as a math problem on a

homework sheet. The engineering students need to learn how to face real-world problems. It should not be the educational system that limits the possibilities.

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