

Preparing the best future engineers through improved teaching methods

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Abstract

Our goal will always be the preparation of excellent engineers for the next generation. However, these new students have different behaviors and aptitudes that limit the effectiveness of traditional teaching methods. This research will focus on how to best approach tomorrow's engineering class with new tools and interactive teaching techniques. Keeping those students engaged and learning for the long term is a challenge. A variety of interactive teaching methods are crucial to make students participate, get more involved at learning in a significant way, that will last their lifetime.

Keywords: excellence in engineering education, interactive teaching methods, hands-on, just in time teaching, peer teaching, clicker, Connect, Jeopardy, Cramster

Introduction

During the last decade of teaching engineering, the quantity of information to learn has increased and the time to acquire this knowledge stayed the same. Maybe the solution to this problem would be to follow the field of medicine, where they now need to have a Bachelor's degree before starting their doctors program. Skills that used to be part of the basic formal education of engineers are gone and replaced by new primordial skills for students of the 21st century. There are skills we expect students to have such as writing a good report, knowing how to use Excel for graph and charts for example. We are not sure if these were taught as time is restricted and materials increased in programs. We witness some gaps in our students' performances across different disciplines. Some are lacking some basic skills and maturity.

Four main issues are prevalent in the new learners of today:

First, today's generation are inundated with a never-ending stream of information throughout their lives. However, they receive this information in non-contiguous bits of visual images— often with no context or reference. Consequently they desire extensive sensory excitement, need to be entertained.

Second, many students arrive without the formal communication skills (report writing) or basic training to use the standard tools (spreadsheets, graphs, tables, word processors).

Third, students have access to resources that might hinder their critical thinking skills and development of a deep understanding of the subject matter. This is due, in part, to access to the popular online study resources such as Cramster¹ where answers to homework are given.

Fourth, students have an expectation that learning is a passive activity and often arrive unprepared for class. With little exposure to the material, the level of retention is significantly reduced.

Both implicated sides need to be examined; the programs with their educators and the tools they use and the learners of tomorrow.

The best way to solve these issues first is to make sure that departments study their programs and lay out a roadmap of all the courses being taught to promote a great flow between courses. This will ensure that no fundamental skills needed to attain excellence in engineering education are missing. In this constantly changing environment, the teachers must take a guidance role to teach all these basic skills, using the best tools available. They need to communicate the required wisdom from the freshman year, all the way up to senior year, to produce the best engineers.

With all the new technologies, the classrooms have changed a lot since 1911. From blackboard and chalk to computers, e-Blackboards, You-tube¹⁸, smart phones and iPads. Students now start to learn in kindergarten with Smart boards in their classrooms, no chalk, no dry marker, just electronics. They have access to Blackboard online in elementary school where they can view information from teachers and their grades on computers. For a school to stay competitive, it must get on board with all this new technology to be relevant and keep the interest of the audience, our students coming from this high technology upbringing. They expect to be entertained and have access to all interactive tools that we can provide to them for learning. This research will try to show that there are many different tools to make your classroom a class of the future and more relevant and reach excellence. It is important to reach all students and give them the best education possible to allow them to succeed in the difficult job market that is the reality of today. Educating the educators might be inevitable as well for them to stay current with all those new technologies.

There are many pieces to this puzzle that we need to figure out in order to teach more information in the same amount of time. We also have several generations of students that learn differently, have greater expectations but also have more passive attitudes. Dealing with these new learners, we need to adapt to take advantage of all this new technology to better educate our students. We also deal with so much access to information that cheating and plagiarism are part of the shared data used to complete homework limiting creativity. Unfortunately a lot of students whether through poor time management or a load too heavy on their semester, copy their homework questions on Cramster¹ or on their friends. The Cramster phenomenon has been shown to be a problem and not a solution in Marc Grams study². Studying the answers and solutions for the exam later is really not the way to understand learning materials, get critical thinking and excel in engineering. This paper will focus on a variety of actions that must be taken to improve the engineering students' quality of learning by promoting a more active role in their own education using more interactive techniques and tools for teaching.

Excellence in Engineering Education

First let's look at what is excellence in engineering education. Forty-seven students took part in a voluntary study³ about excellence in education in 2007 with questions such as "What is excellence in engineering education?", "What is education technology?", "What was their role in engineering education?" and finally "What was the role of the Professor?". Content analysis and keyword frequency were used to analyze the results.

Literature on excellence in engineering education was analyzed in this study³ to bring to light what the stakeholders were expecting for the twenty-first century. A comparison with the students' input on the quality of their education and what is expected from major players driving the movement to improve and maintain excellence in engineering was completed. It showed that students have identified similar points with the stakeholders about what is a great education. Additionally, they identified different ones, personal to them, not identified by the stakeholders dictating the standards. According to this study³, students need more examples in class, hands-on applications and more visual aids. The reports showed that they also want smaller classes for more personal connections.

The major factors defining excellence in engineering education are dictated by the National Academy of Engineering and other organizations such as ABET⁴. They have identified worldwide universities that are making the effort to recognize the challenges engineering programs face and plan to make those changes to achieve excellence. ABET⁴ are in charge of accrediting Universities against a list of criteria and they have raised the standards. A program developed in 2002 created the Center for the Advancement of Scholarship on Engineering Education (CASEE⁵) which is also an important group in dictating excellence in engineering education. They define what should be taught in engineering and define excellence in education in terms of its effectiveness, engagement and efficiency. The Millennium Project⁶ at the University of Michigan studies the future of American Universities providing a joined effort with creative students, faculty and beyond campus to develop new ideas for the University of the future. They propose a learner-centered, affordable and diverse education that is more interactive and adapts to the new era leading to a more sustainable lifelong learning. Balance is the keyword.

Many researchers^{5-8,10} have come up with the same basic requirements that undergrad students in engineering should learn: a combination of knowledge and skills but also wisdom. The latter being hard to define. Fromm¹¹ has defined the characteristics our engineers of the future need such as strong bases in science, math and engineering and the way they can apply those fundamentals to real life problems. The students need to have a good base before they start their engineering program to succeed. They also need to interact with faculty to learn more of that wisdom and ethics that need to be taught in addition to the basic material learned. Having the students' input has helped understand what are their expectations and views on their education.

Interactions between students and faculty are primordial in significant learning and students have spoken³. In two studies^{12,13}, these interactions were important; however,

they were negligible in some cases as was shown in a report from the National survey of Students Engagement NSSE⁹. Pomales-Garcia's study³ showed that under 50% (and even under 30% of students in some universities) don't have interactions with their teachers outside of the classroom. I know from experience that even when the teacher reaches out, is accessible and tries to be helpful, students may not be receptive: Students might have limited time or may be intimidated by the professor. Very few make it to your office unfortunately. E-mail is a great communication tool to stay in touch. Using Blackboard with all that it offers is an extension of your time and hopefully reaches them. We really need to improve those numbers.

Interactive Teaching

Not a lot has been written about how to meet these expectations using the new high technology and mass media world. In 2000, the National Survey of Students Engagement (NSSE) report⁹ showed that students learned more when they were intensely involved in their education. The old fashion lectures are not enough to achieve the high standards of excellence with the new type of audience. Dr. Mazur¹⁴ has been a pioneer in changing the classroom with his "Just In Time (JIT)" teaching style. He has found a way to get the students energized and more involved in their education, which is just what is needed to attain our goal of the best education for our future engineers. JIT style of teaching is where the student must read the material before they show up for class. Questions are asked before class starts and feedback is given before class starts to the instructor so the material can be adjusted to what the students don't understand or find more challenging. It is really making them own their education, having them know about the material before it is taught. This is a brilliant way of getting the science, engineering and math students to read their books before they show up for class. Figure 1 shows an example of a reading assignment in class ENGR221 at the University of St-Thomas. Often just three questions in Blackboard as a form of assignment are enough to know that the student have read the material and the last question always demands them to think of what was the most difficult for them in what they read. The answers are returned in your grading center as a new column with the points that you allocated for each student. You can then leave them a note and respond to their questions. You can define how many points per assignment that you will allow and fit to attain your total of 100% in your grade center for the semester.



Figure 1: Reading assignment from ENGR221 Fall 2011 at the University of St-Thomas.

A combination of these questions individually asked about their reading before class will direct the educator to the material they find difficult and need more attention¹⁴. This new teaching technique takes us away from the traditional lecture and engages more the students in participating and evaluating what he/she does not understand before class.

Dr. Yearwood¹⁵ has also been instrumental in changing the face of education, making strides with new techniques to improve students' role in their education. He has lectured to the faculty development center at the University of St. Thomas (in August 2010) on how to reach students in a classroom with the use of tools and technology. He distributed a Jeopardy game format, which is a Power Point form of documents you can write questions and answers that show up only when you click on them. I adapted this format to questions used in my class on the mechanics of materials. This new approach gets the students more interested and awake and assures the materials taught is revisited. Every chapter can be examined including all fundamental concept in the form of a game. Twenty five questions per chapter on basic concepts are debated in class by teams. The students love it as they are competing in a game, in teams while we are making sure that they understand the material, we revisit every single important points of the learning material for each chapter. At the end of every chapter the game would be played. It brings the fun to learning with the game as well as competition skills that they enjoy. It also introduces peer teaching as they try to convince each other on their team of the right answer. Peer teaching has been also shown to improve students ability to learn significantly as they remember their material better when they can explain it to someone else¹⁴. Figure 2 shows an example of the Jeopardy game for class ENGR221 at the University of St-Thomas.



Figure 2: Jeopardy game chapter 1 for ENGR221 at the University of St-Thomas.

Teachers need to constantly adapt to the tools available to keep the students engaged and connected. McGraw Hill has a new web based system called “Connect”¹⁶ that will allow faculty to provide the student with a more personalized education especially in large classes. These new tools allows the teacher to create homework that needs to be done individually online which remedies copying of homework from friends or a web site such as Cramster¹. They allow us, the instructors, to identify where every student level is at in their learning and address their more problematic issues. When students copy, they lose the instinct that a good engineer needs to identify what should be done to solve each problem. Their critical thinking skill are not being developed. Once the solution is given, students just learn them by heart and then would not know at all what to do if the problem is a little different. Giving online homework with McGraw Hill Connect¹⁶ in this particular class will remedy that. The problem changes for each student going online to complete the assignment so there is no chance of them just copying. It is a win-win situation as it eliminates the copying, forces them to do the work up front and get involved in their learning. The Connect system is paired with your Blackboard and a grade is automatically created in your Blackboard allowing to view the student’s grades, results and make comments on each. The only difficulty here in a multiple step problem is that only the answer is corrected online. If they got it right, you know they understand and the ones they didn’t get, you can request written copies from them so you can see their work and allocate points for the steps they did get right. A homework sample question from ENGR221 this fall is shown in figure 3. All these new approaches to teaching will make sure we will reach those students and get them invested in there education or at least accountable as the solutions have to be coming from them and not from a copy on Cramster¹ or a friend.



Figure 3: Online Homework from McGraw Hill on Connect.

New video capture with Tegrity for McGraw Hill¹⁸ is also a great new tool that gives students access to the teacher 24/7. Complete classes can be captured or specific remote series of small videos of problem solving and techniques. Additionally, explanation of concepts in detail can be made in advanced and put on Blackboard. The students can listen to them over and over and even change the speed of the video to better understand what the educator is saying. It will change the classroom and improve distance learning as well. In figure 4, a still picture of a class video list shows the options students have with the program.



Figure 4: Picture of a Tegrity class video list in ENGR221 Fall 2011.

Clickers as reinforced by Dr. Yearwood¹⁶ are another part of a direct evaluation of what your students know and a great tool to improve our classrooms. You can ask questions in class and know right away if all the students, half the class or just 10% understands. It's a good way to have a read on all your students before an exam is given or at any time during the semester. It is also a good way to involve your student every class. Mini Quizzes also add to identify readily who understands and who doesn't so you can allocate more points to the mini quizzes than to the homework in case they just copied them, which is not a reflection of their level of understanding. Students need to put in the effort in order to get excellence.

The students' favorite parts of class are the projects, where they get to apply the theory to real engineering problems. Students love the hands-on props, labs and projects where they are directly in charge of their work or can visualized or manipulate equipment to understand concepts they have learned. This can also be accomplished by using animated example, videos and real life example. Students still like the more standard tools for teaching such as board and power point presentations but really like to have more applied and hands-on example that they can relate to. Youtube videos are among their favorite technologies used in class. In just one semester, I have personally seen a difference in student's grades by using these new techniques. I went from a more regular basic lecture to adding a lot of the new technology this last fall semester, adding a Jeopardy game and many animated example, You-tube videos and "Myth Buster" episodes. The students responded really well and succeeded.

Conclusion

There are many things that need to be addressed in a classroom. To maintain excellence in engineering education, everyone involved needs to step up and take charge. Departments need to make sure they have a great program that has all that is needed new and old skills the students should have to be prepared for the future. Teachers need to offer dynamic and interactive classes to engage their students and provide them with great knowledge, great skills but also professional wisdom and ethics which they would not get anywhere else before they start on the job market. The students also need to be more involved in their learning and not the rote learning typical when cramming before an exam and forgetting it all in a couple of weeks. The educators with all the new interactive tools and technique will get the students interested and accountable, will individualize their homework evaluation online from using clickers, adding some hands-on work in class and some dynamic example on the book website, using You-tube or video capturing they have prepared for them, using games, props and examples they need. An increase in performance and average in classes and excellence in engineering education is guaranteed. Do we need to consider extending engineering programs by a year or two so students can get a more fundamental base in engineering and then go into a specialty such as doctors in medicine need to do?

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