Responsible Design and Delivery of the Constructed Project
Edited by Abdul-Malak, M., Khoury, H., Singh, A., and Yazdani, S.

ISBN: 978-0-9960437-5-5

REFORMING UNDERGRADUATE STRUCTURAL ENGINEERING EDUCATION: A LEAP OF FAITH

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Do we need to reform civil engineering education? The notable remark about any listing of top universities is that more than 60% of these universities are located in the G8 countries with GDP of more than 60% of the world total. This fact confirms that economic growth is strictly tied to social and cultural development, which is linked to the intellectual and scientific development presented by higher education. This also reveals that the answer to the concern of reforming engineering education is YES. Thus, teaching paradigms must change to fit needs and modes of today's students; they are not interested in passive learning. Active learning must be the path for today's generation of ubiquitous-learning. Different innovative teaching techniques for high-level structural engineering courses have been adopted by the author and proved to be rewarding. Among these paradigms are blended learning and flipped classes, which stretch the utilization of technology in classes. Other new techniques such as student-generated examinations, student-generated classes, design competitions and project-based learning are reflection of student-centered education. Here, the said innovative paradigms, which were recently applied by the authors will be presented.

Keywords: Active learning, Blended learning, Flipped classroom, Teaching pedagogy.

1 INTRODUCTION

The end product of higher education is the graduates; a mirror reflecting the level of success in achieving any program's objectives. Recently a serious and continuous decline in graduates' level of knowledge and skills is noticed; a strong evidence that something is going wrong within the process. Consequently, higher education components (students, faculty, facilities, curricula and teaching/learning paradigms) must be carefully inspected. In Egypt, scrutinizing the students reveals a shocking conclusion: there is no problem with the quality of in-take engineering students. We had, and still have the best students even compared to students worldwide. The second pillar of higher education is faculty. Current faculty rewards are way below the level, which can safely support their social needs and thus, they are involved in other non-academic activities to raise their income. Every day passes without resolving this issue turns this secondary non-academic activity to be the faculty's primary job. Naturally, it takes a valuable share of the faculty's time and the ones who end up paying the penalty are the students. We also have a clear shortage in our facilities; the third pillar. Almost all our facilities starting from our classrooms, laboratories, service areas and even faculty offices need a tremendous upgrade.

Talking about engineering curricula, we always get the famous comment saying: "*we had the best engineering education; when we continued our post-graduate study abroad we high-ranked our colleagues from other universities*". The first part of this statement is true if we modified to: "*we had the best engineering education; then*". At the time of our education, both the curricula and teaching paradigms served the need of this era. However, this does not mean that we must fix both for decades; whatever fitted us does not fit today's students. We must continuously update and improve the curriculum and more important the teaching/learning techniques. We should accept the fact that what we have learned, mastered and excelled in for some time, will always be surpassed by something newer and better; we should not only be willing but eager to accept that it is time to replace what we know with what works better. As such, this article will mainly focus on teaching/learning paradigms, which are also related to faculty to some extent.

If we always think that "*the true purpose of education is to stimulate creativity and passion of the students and the students' body*", we will definitely come to a conclusion that whatever we are doing now should be reformed: it is a leap of faith.

2 OBJECTIVES-ORIENTED CURRICULUM AND OUTCOMES-BASED COURSES

Each engineering program must have its own set of educational objectives, which serve the university and school mission and vision, which in turn serve the overall national higher education mission and vision. Furthermore, the program's educational objectives should reflect the needs of the different program's constituents: students, faculty, and hiring agencies.

Each course within the curriculum should be designed to introduce a certain set of outcomes. When combined, the matrix of the courses' outcomes should form the overall targeted program's outcomes, or attributes of program's graduates (knowledge, skills, values) reflecting the degree to which the program has met its educational objectives. It is worth noting here that curriculum design implementation and evaluation were subjects for many research and discussions (e.g., Walkington 2002, Yeomans and Atrens 2001, Yokomoto and Bostwick 1999). The program's objectives and outcomes significantly contribute toward the curriculum planning, and renewal: they give the ability to change or modify it based on measurable indicators not anecdotes.

Currently, we lack a clear definition of the educational objectives of our structural engineering programs, which is known and familiar to faculty. The only objective of each faculty is the transfer of his/her knowledge within his/her inherited course description to his/her students. Every faculty does this on his/her own with his/her personally defined teaching technique and strategy. In addition, curriculum development is based on an ad-hoc announcement, which came down to faculty individually and everyone/department division has their input which is then collected into a "*new*" curriculum without following any strategy/procedures. To generate an effective objective-oriented curriculum and outcome-based courses, ABET proposed the Continuous Quality Improvement procedures (Besterfield-Sacre *et al.* 2000, Naji *et al.* 2003). Another important aspect is the contribution of all the program's constituencies in defining and assessing the program's objectives and the courses' outcomes. Currently, engineering programs strive to achieve quality. One way of doing this is to obtain national/international accreditation. However, it is imperative that the quality/accreditation procedures become performance-based and not process-based: in the latter, everyone is working to document the quality procedures while in the former everyone is keen to reach into the heart and soul of quality itself.

3 TEACHING/LEARNING PARADIGMS

A brief description of programs' objectives and outcomes were discussed above. However, we must keep in mind that courses of the best-designed curriculum can be delivered in a spontaneous manner with no acquaintance between its courses. Only faculty and department collective body may weave the curriculum's courses to form a solid engineering program. The relationship between the courses presents one significant issue; another vital issue is how each course is delivered. Effective course offering is the only way to benefit the students from a course as opposed to exposing them to a number of sporadic topics, indubitably forgotten as soon as they complete the final exam. Currently, there are pressures on engineering educators everywhere to teach effectively and on the students to learn efficiently in order to meet today’s challenges.

It is very interesting to note that most engineering university professors were not taught anything about teaching: they just follow the footsteps of their professors. Although some are gifted teachers, the majority gains it by trial and error over the years. Today, a lot is known about effective teaching via cumulative professors’ experience (Kauchak and Eggen 2007, Van Rensburg 2003, Wankat 2002). Three aspects control effective teaching and course offering:

1. Learning styles: different ways our students take in and process information.
2. Course planning: the course learning objectives definition course outcomes’ assessment.
3. Instructional approaches: active, cooperative, and problem-based learning techniques.

The first two items were discussed elsewhere (Sayed-Ahmed 2009). In the following sections, different innovative teaching/learning techniques for structural engineering courses adopted by the author and proved to be rewarding will be presented. Among these paradigms are blended learning and flipped classrooms, which stretch the utilization of technology in classes. Other new techniques such as student-generated examinations, student-generated classes, design competitions and project-based learning are direct reflections of student-centered education.

3.1 Flipped Classroom

I have applied this technique to some topics in one of the advanced reinforced concrete design courses (CENG 4158: Structural Systems and Advanced Design) in multiple semesters.

In this paradigm, lectures are uploaded online in form of mini-videos (less than 12 minutes each) along with the common lecture notes in PDF format. Online assessments are added after each part in order to enhance the students’ perception of the online materials. Students are asked to watch the mini-videos, read the notes and go through the online assessment prior to the class. Furthermore, an activity is assigned to the students and they were asked to work on it and bring it to the class. During the normal face-to-face (F2F) class, the time is used to perform advanced practical application related to the online materials: active/collaborative learning is adopted based on the knowledge, which the students gained prior the class. Group work and discussions between the students actually engage almost all the students in an enthusiastic environment. In other words, class time is used for concept engagement and collaboration with peers in higher order practical applications under my direct supervision and guidance as a mentor. Figure 1 compares F2F class time for both traditional and flipped classroom paradigms.

Traditional Class Time	
Activity	Time
Warm-up & previous info	10 min
Lecture new content	45-50 min
Independent activity	10-15 min

Flipped Class Time	
Activity	Time
Warm-up activity and previous info	5 min
Q&A time on mini-videos	10-15 min
Guided teamwork practice activity	50-55 min

Figure 1. Comparison between class time in flipped and normal classrooms.

3.2 Blended Learning

Recently, I have designed and offered a blended learning course (CENG 592/5292: Advanced Topics in Construction Engineering: Design and Construction of Steel Structures). AUC defines blended learning as a combination of F2F and online instruction, which entails replacing 30% of the class time with online instruction. This BL course used a model of a sequential F2F/online.

BL proved to be very effective particularly for such graduate level course where students may have different levels of entry skills and knowledge. It provides them with self-paced coverage of materials and allows them to perform self-assessment. F2F class time is saved for discussion of content, and practical application after bringing the student to the same level of knowledge.

The online part of the course was designed to include mini-videos, lecture notes, e-assessment, active e-discussions, etc. The main purpose of the online part is to bring graduate students with different backgrounds to the same level before each face-to-face (F2F) class, which includes normal lecturing, students' presentations, assignments, mini-projects and case studies.

3.3 Student-Generated Examinations

As John Dewey said, "*if we teach today's students as we taught yesterday's, we rob them of tomorrow*." Hence, the idea of starting student-generated examinations. A mid-term exam of one of my courses (CENG 4113: Structural Mechanics) has now regularly become a student-generated examination. Each student (or groups of two students) submit a mid-term exam on pre-specified topics. Each exam is accompanied by a model answer and a mark scheme. This mark scheme defines both the grade distribution and all possible alternatives for the solutions and mistakes. In class, exams are randomized and distributed to students; each student solves one of his/her colleague's exam. The student's grading of this mid-term exam is distributed as 50% on preparing the exam, its model answer and mark scheme and 50% on solving other student's exam. Recently, I have added a 5% grade on the difficulty level of the exam, which I assigned on each of the submitted and solved exams. The assigned time for the exam is 60 minutes with no limit on the number or distribution of exam's questions. It is, of course, an open book exam.

I have superb outcomes out of this pedagogy such as

- The range of items covered by students' questions is astonishing.
- The exam defines part(s), which students see as "the most important content" and other over-looked items in my classes.
- Most students study beyond the content and the lecture notes in order to be able not only to assign the question but also to prepare its mark scheme.
- The exam also reveals to me the students' perception of "fair" and "useful" questions and how well they answer the questions they created.

3.4 Student-Generated Classes

At the last three weeks of the semester, I leave topics of one of my courses (CENG 4113: Structural Mechanics) for the students to generate classes; these topics are introduction to fracture mechanics, beams/rafts on elastic foundation and theory of plates and shells.

Students are arranged in groups of two-to-three students each and specify the topic for each group. Then, I ask them to prepare one (or two) full class(es) on their topic in any form of lecturing and, in addition, they must present practical applications (in forms of solved examples, or any other form) and give their colleague an assignment on this topic to solve.

I have recorded multiple outcomes of this teaching/learning pedagogy. Students really appreciate the need for life-long learning, which is indeed my primary teaching goal. Each group performs a research-like activity and presents their findings to their colleagues; they also feel responsible for getting these findings to their colleagues during these lectures.

3.5 Project Based Learning (PBL)

PBL is a learner-centered teaching practice, where students collaboratively engage in solving complex and challenging real-world problems. The motivation to solve a problem drives them to learn the required/intended content. The problem actually becomes a vehicle for stimulating the cognitive process and developing problem-solving skills. I have implemented PBL in one of my classes (CENG 4911: Selected Topics in Construction Engineering – Design of Steel Structures) in form of a case study on a collapsed steel building. This case study presented a real engineering problem related to a building which partially failed during construction, and thus, needed rehabilitation and strengthening. The LMS discussion board was adopted to post (and discuss) alternatives for the reason(s) creating this engineering problem and for alternative solution(s) to rehabilitate/strengthen the structure presented in the case study. The first part (cause of failure) was performed as a "guided" discussion. Based on the first topic outcomes, the second topic (repair) was opened for discussion. Figure 2 shows the problem statement. It was accompanied by a PP presentation, drawings, photos and a video.

Figure 2. Problem statement and details adopted for BPL.

Students were so enthusiastic to analyze the structure in order to find its cause of failure by using all what they have learned in this course and others. Then, once we agreed on the main cause of failure, they endeavored to find the best method of repair in a very active atmosphere.

3.6 Course Competitions

I have generated two design competitions in some of my design courses. The first one is building and testing columns using Spaghetti and while the second includes building, analyzing and testing a bridge model created using a set of tongue pressers. The students compete to reach the best design where the intended learning objectives of these competitions are; motivating students to learn design concepts using non-traditional materials, enhancing the teamwork capabilities of the students, adopting design/build techniques, enhancing the students' engagement in my class. I follow a simple methodology where students' groups are formed and materials are distributed with a definition of design constraints. In the design phase, students choose an appropriate design and construct their models. For the bridge competition, students create a numerical simulation for their models in order to predict the failure load. This stage needs material testing as well in order to estimate the mechanical properties of the tongue pressers. The last stage is testing the model in order to experimentally predict the failure load. Ratios between this failure load to the predicted one and the failure load to the model weight were established. The winning team (100% of the grade) is the one achieving the first ratio closest to 1.0 and maximum value for the second ratio.

Figure 3. Design competitions: spaghetti columns and tongue presser bridges.

4 SUMMARY

Our teaching/learning paradigm in structural engineering courses must be updated to fit the needs and the challenges facing today's students, and more important, to get them engaged and interested to what they are learning. This article presents new paradigms such as flipped classrooms, blended learning, student-generated examinations and classes, project-based learning and design competitions which were applied to different senior or graduate design courses. They are revealed to be very effective in achieving the intended learning outcomes and in emphasizing to the students the importance of lifelong learning.

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