A Blueprint for a Holistic Approach to Teaching/Learning of Fundamental Engineering Courses

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Abstract

Fundamental engineering courses have been perpetually challenging and often frustrating for students, faculty and administration. High number of failure, "D" grade, and withdrawal, (FWD); insufficient high-level learning of fundamentals observed in the subsequent analysis and design courses; low level of cognition and inadequate capability for knowledge integration, demonstrated in the senior design capstone projects, are some of the symptoms pointing at serious challenges in teaching and learning these courses.

This study is intended to compile a list of published methodologies and strategies related to improving teaching/learning STEM courses in general, and fundamental engineering courses in particular. The list will then be categorized and will be utilized as a blueprint to review the state-of-the-art of scientific teaching in order to document the problems that have been identified and the methods and techniques that have been proposed to address the identified problems.

Key words: Effective teaching, scientific teaching, active learning, learning styles

Introduction

Teaching and learning fundamental engineering courses have been challenging for instructors, students and administration. Statics and Strength of Materials, which is a required course in several engineering disciplines, has been notorious as a killer course, because of its large rate of FWD nationwide. A great number of studies have been carried out in identifying the root causes of the problems in teaching/learning engineering fundamental courses. Methods and techniques have been proposed to address one or more of the perceived major impeding factors in the road to accomplishing efficiency in teaching and learning.

These studies, generally, have concentrated on a single factor deemed to be the major parameter. However, in practice the effect of a single parameter on a course has not been considerable. Moreover, the proposed techniques have not been readily adopted by educators. Many instructors, not being aware of such researches, have been repeating them unnecessarily and often unsuccessfully by trial and error. Because scientific teaching is multifaceted, a systematic approach is required to deal with its key elements in a holistic manner. First of all the major factors need to be identified, and then the appropriate techniques should be applied in a comprehensive holistic approach. This holistic approach

needs to be disseminated to the faculty. Some of these studies aimed at improving learning/teaching are briefly described below:

Active Learning

The traditional didactic approach, that is the lecture based delivery of course content, has been found to be less effective in 21st century classrooms and is in need of revision. Constructivist theory has proven to be a better alternative which has led to various versions of active learning, (AL), also called student-centered learning. According to Arnaud (2014)[1], active learning beats lecture. Active learning techniques such as problem based learning; (PBL) has led to a complete reversal of the structure of traditional lecture based course delivery. One innovative method in this category is flipping classroom. To flip classroom, the instructor places short videos of course content online for the students to study outside the classroom. The class time is spent for discussion, clarification and problem solving. Flipping classroom is currently being experimented widely although the initial data on effectiveness of flipping is not very conclusive. As expected, only flipping the classroom will not solve the multifaceted problem at hand.

There is evidence that active learning, student-centered approaches to teaching physiology work, and they work better than more passive approaches (Michael, J., 2006)[10]. At colleges nationwide, more and more professors are inverting homework and classwork, using technology to give students a head start on classroom sessions where they can be active participants and not just listeners (Mangan, K., 2013)[8].

Learning Styles

Whether or not learning styles of students should be considered in classroom is controversial. Some instructors are questioning the practicality and cost effectiveness of the idea. However being aware of learning styles makes the instructor to be sensitive to diversity and this on itself is a positive point.

Styles are of interest to educators because they predict academic performance in ways that go beyond abilities (Marton & Booth, 1997)[9]. They are also of interest because when teachers take styles in account, they help improve both instruction and assessment. Moreover, teachers who take styles into account can show sensitivity to cultural and individual diversity that is so often absent in classroom (Sternberg et al, 2001)[13].

Bostrom (2004)[2] found positive connections between methods adapted to the student's individual learning style (an "adaptive learning environment") and their learning and motivation. It became evident furthermore that learning strategies could be mobilized, developed and utilized in such adaptive learning environments (Bostrom et al, 2006)[2].

Assessment

Assessment is a measure of determining the extent of learning that is taking place in a classroom. Based on a thorough analysis of the collected data a better plan for future can be

designed. It shows the instructor how to improve and fine tune or completely alter their instruction method. Frequent formative assessments, of course, are more effective than summative end of semester exams.

Assessment is widely regarded as playing a key role in establishing and in raising standards of learning (Stobart, 2008)[14], as well as serving a multitude of purposes ranging from facilitating learning in classrooms to monitoring school performance and national standards (Harlen, 2007)[5].

Motivation

No matter what the course delivery method, if the students are not motivated to learn they won't learn. Some students are self- motivated, but others, who are on the fence, can be encouraged to work harder or discouraged to quit.

Motivational strategies help the student generalize or apply the information given in the class. Many psychologists argue that one person cannot motivate another, but experience has told teachers that one can make the students want to learn. Even dry course material can be made interesting with the incorporation of motivational strategies (Kittrell & Moore, 2013)[7].

Pre-requisites

Science and engineering courses in freshman year of colleges require a certain level of background to build upon, without necessary pre-requisites can discourage freshmen. Appropriate placement and student advising will address issues associated with inadequate or forgotten background content knowledge and can impact, in a positive way, students' attitudes and success in a course (Pyzdrowski et al, 2012)[12].

Dissemination

Acceptance in use of innovative pedagogical means and methods has not been widespread among the faculty. Hazen et al (2012)[6] have demonstrated factors that influence (impede or enhance) dissemination in engineering education. They have identified logistical issues and cultural differences as chief impediments.

Instructor Qualifications

Although graduate study affords excellent preparation for many careers because, it teaches people to think, reason, and analyze, many Ph.D. recipients enter careers in teaching for which they have no formal training (Handelsman et al, 2007)[4]. Teaching skills has been left to be developed by trial and error. Because tenure and promotion process relies heavily on student evaluation, the new faculty members are reluctant to take the risk of trying new methods of innovative pedagogy; therefore the old fashioned lecture based delivery is still the preferred method. Character traits of the instructors such as caring about students, patience, discipline, and interest in pedagogy, play significant roles in creating rapport with students and as a result, can encourage and motivate students.

Teaching Assistants Qualifications

Graduate teaching assistants (GTAs) in science, technology, engineering, and mathematics (STEM) disciplines have and are going to continue to have a large influence on the teaching of undergraduate students (DeChenne, S. E. et al, 2012)[3]. Majority of students are at ease with their GTAs and frequently use the GTA's office hours, while they are reluctant to use the office hours of their professor.

Classroom Configuration

Physical space of the classroom and arrangement of seats as well as electronic equipment such as computer, document camera and projector play a significant role in efficiency of teaching and learning. Traditional lecture based classrooms do not lend themselves to modern active learning techniques; active learning requires its own specific classroom design and set up.

Higher education institutions should pay more attention to the educational impact that classroom design has on students, and make investment in healthy learning spaces a priority (Park, E., L., Choi, B., K., 2014)[11].

Physical and virtual models

Presenting new concepts will be more effective if complemented by demonstrating pictures, physical models, video clips and animations. Simulation-based learning tool can be used as an alternative to physical experiments.

(Yu-Lung, C. et al, 2011)[17] report that learning performance was higher for learning software utilizing simulative manipulation and visualization than for that lacking simulative manipulation, which suggests that learning performance can be enhanced if visualized learning can appropriately integrate simulative manipulation activities.

Textbook

In order to select a textbook for a course, the instructor may look for features such as: richness of the content; logical sequence of chapters; quality of figures, graphs and tables; example problems, problems at the end of chapter and availability of teaching aids. E-books as a lower cost alternative can provide additional features like availability, hyperlinks and other features that add to the richness of content.

Tessier (2014)[15] proposes eliminating textbook and learning science with cell phones. Woody, Daniel and Baker (2010)[16] argue that Students prefer textbooks and conclude that much more research is needed to identify and remedy differences due to the physical medium (e.g. eye-strain, navigation, etc.) as well as user differences in habits for interacting with electronic text before e-book can be considered viable alternative to printed textbook.

Objective of this research

The objective of this study is to compile a comprehensive list of the major factors for improving teaching and learning that have been researched and published. This list will be used as a blueprint for the upcoming research that will review the state-of-the-art of scientific teaching to prepare a concise document as a reference for the faculty involved in teaching fundamental courses in engineering.

Major Parameters Identified for Efficient and Effective Teaching/Learning

The following list, based on the current pedagogical research literature, contains the major topics that can influence efficiency of teaching/learning process. This list demonstrates that teaching and learning is indeed a multivariate process. Therefore no single factor can impart a considerable improvement on the outcome. Each item in this list needs a rigorous scrutiny to reveal its degree of efficiency and effectiveness.

1- Active learning
2- Learning styles
3- Assessment
4- Motivation
5- Pre-requisites
6- Dissemination
7- Instructor qualifications
8- Teaching assistant qualification
9- Classroom configuration
10- Physical and virtual teaching aids
11- Textbook

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