

The Need for a Structured Approach to Teach Engineering – Some Preliminary Thoughts

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Abstract : Engineering education has seen lot of changes in the last fifty years. There has been a drastic change in the way engineering education is delivered today than it was before. In today's world, the emphasis is on 'outcomes', and we are supposed to follow the 'outcomes based education' (OBE). The accreditation methodology adopted by the National Board of Accreditation (NBA) is outcomes based, where the focus is on the student (learner), rather than the teacher. In this scenario, the approach to teach engineering also should undergo a change and accordingly, this paper provides some thoughts on the need to follow a structured approach to teach engineering. The formal training of teachers is very much essential, as teachers lack awareness about the need to follow a proper methodology when they teach their students. A two day workshop carried out at the authors' institution has provided some valuable feedback regarding the need for such a structured approach to teach engineering. Such kind of programs / courses will go a long way in improving the quality of teaching and make the teachers more oriented towards OBE.

Keywords: teaching engineering, outcome based education

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1. Introduction

India has one of the largest technical education system in the world, with more than 1 million engineers graduating every year from more than 5000 engineering colleges, which include government, aided and private. Engineering education has seen lot of changes in the last fifty years in the teaching pedagogy, teaching-learning process, use of information and communication technology, evaluation process etc. The focus has shifted from 'teacher' to 'student'. The education delivered to the students has become 'outcomes based', with emphasis on learning outcomes rather than grades and assessment. The adoption of Outcome Based Education (OBE) will help all stake holders namely students, parents, institutions, employers and government. This will help in improving employability of students and India is a Permanent signatory of Washington Accord, which facilitates global mobility (Rao, ORS, 2013). In this regard, there is a need to adopt OBE by all engineering institutions in the country.

The need for maintaining necessary standards in engineering education is a must to meet these requirements. There is also a need to streamline the engineering education in the country. The requirements of OBE, the exponential increase in the number of institutions offering technical education, the diversity of student population, the advancements in science and technology are some of the factors which require the reorientation of engineering

education to make it more current and relevant. There is a need to improve the teaching-learning process, which is one of the important component of the technical education system, other two being R & D and social outreach. The students getting into technical education are from diverse backgrounds and the use of one approach is not suitable. Students are technologically savvy these days and there is a need to adopt mixed approach to teaching, which includes the use of chalk and board and the use of information and communication technology (ICT).

Teachers need to use ppts and LCD projectors, make use of E-learning resources, MOOCs etc. The use of technology supports the delivery of education both in synchronous and asynchronous mode. Accordingly the modes of evaluation are also changing. The adoption of Choice-based Credit System (CBCS) by most of the Universities in India has increased responsibility of teachers. There is a need for continuously evaluating the performance of the students, for which innovative methods of evaluation need to be devised, other than the use of assignments and tests.

In this changed scenario, where the focus is not only on what students are learning, have learnt, when they complete their degree, but also to know how they are faring after completion of their graduation, which is the crux of OBE, there is a need to reorient the teachers about their role in the institutions. There is a need to improve the teaching-learning process, fulfilling the requirements of mandatory government bodies like AICTE / UGC, getting accreditation, improve and maintain the quality of technical education, use of ICT effectively and improve the evaluation process. There is a need for a formal training of the newly recruited faculty on all these aspects. This could be through Faculty induction programs, summer / winter schools, workshops, certificate courses or maybe even a degree program. There have been some efforts going on in the country through winter and summer schools organized by ISTE, New Delhi, AICTE, or through the programs offered by NITTTRs etc. Also at the Institution level, there are some formal orientation programs being carried out, which do not fulfill all the requirements.

There is a need to train the teachers by offering them a dedicated workshop or a certificate course, which will provide them an overview about different aspects of effectively teaching engineering. The

teachers are considered to be competent in their domain knowledge, but there is a need to orient them to teach a course in a particular way to meet the requirements of the students. There have been efforts going on all over the world in various Universities in this connection. Many well-known Universities like Purdue in USA offer a semester long course. Well known researchers in the area of engineering education like Prof. Richard M. Felder from North Carolina State University, USA and Prof. Philip C Wankat from Purdue University, USA have written very well researched articles and books about 'how to teach engineering effectively'. There is a need to make use of these resources and frame a formal course curriculum which will cover various aspects.

Accordingly a two day workshop was carried out about this theme in the authors' institution, which has provided valuable feedback about the need of such a program / course. Thus this paper will review some of the literature about various issues related to teaching engineering, cover a few well known programs offered in some Universities and discuss the feedback collected from the participants of the workshop.

2. Literature Review

This section tries to review some literature, which discusses about the need to have such formal courses or programs on engineering education or discusses certain aspects related to the same.

One of the pioneering papers on 'teaching engineering' has been by Richard M. Felder and Linda Silverman, which was published in *Engineering Education* in 1987. It has 5070 citations till date. It discusses the different learning and teaching styles relevant to engineering education and accordingly they have developed a self-scoring web-based instrument called the 'Index of learning styles', which assesses the preferences on four scales of the learning style model, which gets several hits a year and has been translated into several languages (Felder R.M., 1988). In 1995, Richard M. Felder and E.R. Henriques modified the model that they developed by dropping the inductive / deductive dimension and changing the visual / auditory category to visual / verbal (Felder & Henriques, 1995).

The Teaching Assistant Fellows of University of Wisconsin, Madison (1996) prepared a Handbook for teaching assistants regarding 'Strategies for Effective

Teaching'. The strategies covered three broad objectives – educational excellence, research leadership and technology transfer leadership. They identified ten categories of effective teaching strategies, each consisting of introduction, scope, examples and conclusions, which also included student responses to these strategies (Courter S et al., 1996). Pamela M. Norris and Sheila C. Palmer (1996) discussed about a unique teaching internship program implemented at Georgia Institute of Technology in 1990. This program was meant for Doctoral students who wanted to get into teaching. This provided them an opportunity to gain experience under the guidance of faculty member, in conduction of a course and receive feedback from the faculty mentor. The data was obtained from a survey of former students and faculty participants. The data was suitably analyzed and the findings were presented in terms of its advantages, limitations and feedback from all the stakeholders to improve this program (Norris & Palmer, 1996).

Richard M. Felder et al. (2000) discussed about the wide variety of teaching techniques which have been shown to be repeatedly effective in the context of engineering education. They suggest some themes, which include – (i) Formulate and publish clear instructional objectives, (ii) establish relevance of course material and teach inductively, (iii) balance concrete and abstract information in every course, (iv) promote active learning in the class room, (v) use cooperative learning, (vi) give challenging, but fair tests and (vii) convey a sense of concern about student's learning (Felder et al., 2000). Anne K. Ditcher (2001) presents the need to change in teaching engineering education and the factors include changing needs of employers, need for flexibility and lifelong learning. To bring about this change, there is a need to understand the factors that affect student learning and the factors considered include – conceptions of learning, approaches to learning and the learning context. According to the author, one approach that forces students to take responsibility for their learning and ensures active and deep involvement is problem-based learning (Ditcher, 2001). Ronald Welch et al. (2001) discussed the outcomes experienced by a team that underwent the ExCEED Teaching Workshop (ETW) held in 2000. It is an American Society of Civil Engineers (ASCE) sponsored one-week workshop offered at the United States Military Academy (USMA) and the University of Arkansas. This workshop provided necessary

foundation for achieving teaching excellence. The team had six faculty members drawn from different Universities, who adapted what they learned during the workshop and through self-assessment, assessment by peers and students. The teaching hints identified were categorized into four areas – organization, preparation, practice and rapport. The effectiveness of these hints was discussed with respect to teacher performance evaluations, student feedback and self-assessments (Welch, et al. 2001).

Amin Elshorbagy and Dieter J. Schonwetter (2002) reviewed a number of important aspects of engineering education. Kolb's cycles of learning was discussed. They highlighted the significance of inductive method of instruction as effective for teaching UG students. According to them, there is a need to carefully assess the performance of the students taking into consideration Bloom's taxonomy (Elshorbagy & Schonwetter, 2002). Philip C. Wankat et al. (2002) discussed the impact of scholarship of teaching and learning on engineering education. They reviewed the literature related to American engineering education from 19th century till date and presented the development of scholarship of teaching and learning and the current challenges. They also assessed as to how it can be included in the faculty reward system (Wankat P C et al., 2002).

Warren Houghton (2004) while drafting a report for The Higher Education Academy – Engineering Subject Centre presented the relevance of Learning and Teaching theory to teaching engineering (Houghton W., 2004).

L. Dee Fink, Susan Ambrose and Daniel Wheeler (2005) provided a conceptual framework for responding to the challenges in engineering education to meet the demands of engineering profession in the 21st century and to become a professional educator. They asked two questions and answered them through relevant case studies namely – what do we know about professional development of faculty and what else do we need to learn and do? Their second question required research, sharing of best practices and selection of national initiatives (Dee Fink L et al., 2005). Michael J. Prince and Richard M. Felder (2006) discussed about newer teaching methods like – inquiry learning, problem-based learning, project-based learning, case-based teaching, discovery learning and just-in-time teaching. They discussed different methods highlighted the common features

and differences and reviewed research on effectiveness of these methods. They established that inductive learning methods are more effective than deductive methods for achieving a broad range of learning outcomes (Prince & Felder, 2006). Sherrill L. Sellers et al. (2007) developed a resource called 'Reaching All Students', which was developed by the Diversity Team of the Center for the Integration of Research, Teaching and Learning (CITRL), a NSF funded multi-institutional project of the University of Wisconsin-Madison, Michigan State University, The Pennsylvania State University, The University of Colorado-Boulder, Howard University, Texas A-M University and Vanderbilt University. It is a compilation of articles from universities across the country related to STEM fields. This resource provides instructors with tools for teaching. It covers the life of an entire course starting from planning the class, choosing teaching methods, to end-of-semester evaluation of oneself and the students (Sellers S.L. et al., 2007).

P.Kapranos and P.Tsakiropoulos(2008) presented some thoughts on teaching engineering students. They draw the attention of the readers to interrelated issues of education and training of significance to engineering. They also discussed basic theories of teaching relevant to engineering (Kapranos & Tsakiropoulos, 2008).

Peter J. Goodhew (2010) in a book written for The School of Engineering's Active Learning Lab at the University of Liverpool has provided insights into effective teaching of engineering at the undergraduate (UG) and post graduate (PG) level. He evaluates existing teaching and learning techniques, so that they can be successfully used in the classroom. The book guides the teachers about the various issues related to the teaching-learning process and provides necessary directions for the future ahead (Goodhew P.J., 2010).

This literature review presents briefly the efforts going on in various Universities and the research work related to the need to have a formal program / course on 'Teaching engineering'. The programs offered cover all the basic aspects of teaching-learning process. The effectiveness of these programs has established its use among the teaching fraternity. There is a need to have such a formal training of teachers to make them aware about the science behind the teaching of engineering. In the next section, two literatures will be discussed in detail to understand the

issues with regard to the formulation of a program or course regarding 'teaching engineering' and a typical topics list is presented. The conduction of the two day workshop on structured approach to engineering and the feedback received will be discussed.

3. Formulating A Program / Course For 'teaching Engineering'

The need for such a formal program and course on 'teaching engineering' is well understood. From the literature and looking at the programs offered by different Universities, it can range from a two day workshop to a full semester credit based course. It can be a continually offered program so that teachers are made aware about the recent research trends and findings with regard to effective methods of teaching, the developments in pedagogy etc.

Christopher H. Conley et al. (2000) discussed about T4E, a week long short course run at the US Military Academy at West Point, NY. This course provided a firm foundation of doing effective teaching. The focus of this program is to have well organized classes that promote active participation of students. This program was based on Instructor Summer Workshop (ISW), a rigorous annual six-week teacher training program by the Dept. of Civil & Mechanical Engg. at the US Military Academy. To compress a six week training program to a week long course needed the development of a model, which was called the T4E. The model consisted of both content – a set of fundamental teaching principles and process – a learning environment, where the faculty members practiced the application of these principles. The teaching principles emphasized in this model were as follows – use structured organization of content to guide the learner, use effective communication, demonstrate enthusiasm for the subject matter, for teaching and for learning, use homework and projects to promote learning outside the classroom and use technology when and where it enhances the learning process. The process constituted a collaborative learning environment in which the participants master the fundamental principles described before. This is based on the idea that participants learn to teach effectively by - watching others teach, sharing ideas about teaching with others, teaching, receiving rigorous and constructive feedback about their teaching and finally learning to self-assess the quality of their own teaching. The T4 E course included seminar, demonstration class and lab. The evaluation

included course-end assessment and follow-up assessment. This course fulfilled a critical need of providing a coherent and highly focused training of teachers, it was highly regarded by the participants, it provided a valuable set of tools for the participants and the participation of the participants in teaching actual classes, which produced significant improvements in teaching and self-assessment skills (Conley C.H. et al., 2000)

Ronald Welch et al.(2001) discussed the results of experience of a group of teachers at ExCEED (Excellence in Civil Engineering Education) Teaching Workshop (ETW). It is an American Society of Civil Engineers (ASCE) sponsored one week workshop offered at the US Military Academy and the University of Arkansas to promote teaching excellence. The team consisted of 6 faculty members drawn from several Universities from the country implemented what they learned at the workshop and offered some successful teaching hints for effective teaching which can be categorized into four areas namely organization, preparation, practice and rapport. Some interesting conclusions drawn from the participants included need for formal instructor training for all faculty, the granting of a degree like PhD does not automatically give teaching skills to teachers. There is a need to understand the theory and practice of effective teaching. There is a need for the faculty to manage their teaching considering the above areas, so that teaching becomes effortless and fun. Teaching plays a very important role in building the nations' manpower, to promote growth and prosperity of a nation (Welch, R. et al., 2001).

These two literatures provide information about the methodology used for offering such a program about 'teaching engineering', to provide information about the various issues important for teaching and the outcomes of such programs. Both the literature emphasize the need for having such a formal program for training teachers.

A typical course / program content may include the following topics, but are not restricted:

- i. Significance of teaching engineering
- ii. Teaching-learning process
- iii. Learning principles

- iv. Teaching efficiency, research efficiency
- v. Designing the class work - course preparation – preparation of course objectives, Application of Bloom's taxonomy, developing course content, selection of text books, fulfilling the accreditation requirements.
- vi. Problem solving and creativity
- vii. Teaching pedagogy – lectures, alternate methods of teaching – discussions, cooperative group learning, field trips and visits etc.
- viii. Use of technology in teaching – TV and video, computers, audio etc.
- ix. Design of laboratory classes
- x. Other roles of teacher – professional and personal issues
- xi. Evaluation process
- xii. Student discipline and ethics
- xiii. Teaching – learning theories
- xiv. Teaching evaluation

These contents have been drawn from the text book by Philip C Wankat (Wankat, & Oreovicz, 2015).

4. Details Of Workshop Conducted And The Feedback Analysis

Accordingly, a Two-Day workshop on “Structured Approach in Engineering Education for Quality Enhancement” was organized in the authors' institution. About 30 faculty members attended this workshop, which included three external participants from nearby engineering colleges. The topics covered in the workshop included - Teaching Engineering, Introduction to Outcome Based Education (OBE) and Outcome Based Accreditation (OBA), Bloom's Taxonomy for Outcomes, Problem Solving &

Creativity and Challenges in Engineering Education.

Session 1 – This was related to 'Teaching Engineering'. The speaker covered the following topics – overview of the topic, teaching methods and styles, designing and presenting the course content, evaluation and assessment, problem solving and creativity, role of an engineering teacher and an ideal undergraduate engineering curriculum. The session was for about 2 hours. The feedback was provided by all the participants. The positive aspect was that all the participants appreciated the content, explanations provided, examples given, appreciated the information about learning methods and styles, understood the gap in teaching students, about their behavior and mentality, it created awareness about the topic and also the participants understood the issues related to proper evaluation. The overall response was favorable; where the participants appreciated the topics covered and felt the need to conduct more such workshops. However the negative aspects included, too much content presented in 2 hours duration, ppt preparation needs to be improved, serious session, need to present solutions to problems encountered during teaching, more examples to be given for better understanding and an overwhelming response was regarding time constraint. The participants expressed the need to provide this information in 2 or 3 sessions.

Session 2 – Introduction to OBE and OBA - The speaker covered topics like overview of OBE, OBA, difference between NBA and NAAC, brief introduction to ABET and difference between CO, PO and PEO and how to map them. The session was for one and half hours. The feedback was provided by 28 participants. The positive aspects included very informative, understood the differences between NBA and NAAC, about CO, PO and PEO and how to map them and general awareness about OBE and OBA. The overall response was positive. But some suggestions given for improving the outreach of the topic included provide information about effective implementation, provide case studies and cover assessment in detail. The common suggestion was to increase the time allotted for this topic for more detailed presentation.

Session 3 - Blooms' Taxonomy (BT) for Outcomes – The speaker covered different aspects of Bloom's Taxonomy, older and newer version, its use in assessing the levels of questions in the question paper and how to use them effectively. About 21 feedback

responses were received for this session. The participants appreciated the need for using BT for preparing questions in the question paper trying to cover all the levels, understood the concept, differentiated between different levels, but felt the need for active participation by the speaker as well the participants in the form of discussions to better understand the implementation of the same.

Session 4 – Problem solving & creativity and Challenges in Engineering Education – The speaker, a management expert covered the topics from a management perspective. About 24 responses were received, where the participants understood the concept of creativity, problem solving, there was good explanation with examples and found it to be useful for effective teaching. However some of them felt, it was not related to teaching engineering, there is a need for active learning and it is more oriented towards management with few jargons which were difficult to understand.

An inspiring you tube video about the significance of teaching by Prof. Philip C Wankat of Purdue University, USA was presented to provide an international perspective about the theme of the workshop.

The participants felt benefited from this workshop and felt the need to conduct this workshop regularly. This feedback has motivated the organizers and they have decided to organize this workshop on a regular basis, covering all the faculty of the institution to drive home the point that teaching engineering is a complex task and is based on sound research related to various aspects including teaching-learning, learning styles and methods, preparation of course plan, curriculum design, use of information and communication technologies, continuous assessment and evaluation, writing course outcomes, mapping it with program outcomes and program educational objectives and use of BL in framing questions in the question paper, multiple roles of teachers in the current context etc.

There are lots of resources available, which can be used by teachers for improving their teaching skills and to understand the scientific and research background of the same. Some resources that the authors feel are very useful are listed below –

1. Philip C Wankat & Frank S. Oreovicz, "Teaching Engineering", Second

Edition(ePub), Purdue University Press, 2015, ISBN 13: 9781612493626.

2. Heather Fry, Steve Ketteridge & Stephanie Marshall, "A HANDBOOK FOR Teaching and Learning in Higher Education – Enhancing Academic Practice", Third Edition, Routledge (Taylor & Francis Group), New York and London, 2009, ISBN 0-203-89141-4 Master e-book ISBN.
3. Caroline Baillie & Ivan Moore, "Effective learning and Teaching in Engineering", RoutledgeFalmer (Taylor & Francis Group), New York and London, 2004, ISBN 0-203-41598-1 Master e-book ISBN.

There are several research papers and articles, used in the preparation of this manuscript, which can be used for getting the necessary information about issues related to teaching engineering.

5. Conclusions

Teaching engineering has undergone a paradigm shift in the last few decades. The teaching-learning process has seen lot of changes after the acceptance of OBE in the technical education. Teachers in engineering education have to face lot of challenges which include increased number of students opting for technical education, diversity of students, internationalization of students, advent of globalization, developments in the field of information and communication technologies, "digitally smart" students, increased expectations from the students, parents, employers and society in general.

The increased number of technical institutions in the private sector in the Indian context has led to deterioration of quality of technical education. There is a need for the teachers to balance all these challenges and fulfill the expectations of all the stakeholders. This is a question of survival for them as there are increased demands from the management. There are also issues of the teachers, which include personal developments like completion of their PhD degree, get promotions, conduct research, produce publications, get funding, get incentives etc. which have made teaching profession all the more difficult.

In this changed scenario, there is a need for the

teachers to adopt newer pedagogies for making their teaching effective. There is less awareness among the teachers in India about the science and research behind effective teaching. In this regard, this paper tries to review the latest literature regarding the science, philosophy and research regarding effective teaching, highlighting their findings. Also some information about the conduct of a two day workshop at the authors' institution regarding structured approach to teach engineering and the feedback received from the participants is presented. The overwhelming response from the participants is there is a need to conduct such workshops on a regular basis and provide formal training to improve their teaching-learning skills.

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