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Enhancing Teaching of Engineering Mathematics

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***Abstract*—**Teaching of mathematics to engineering students is an open ended problem in education. The main goal of mathematics learning for engineering students is the ability of applying a wide range of mathematical techniques and skills in their engineering classes and later in their professional work. Most of the undergraduate engineering students and faculties feels that no efforts and attempts are made to demonstrate the applicability of various topics of mathematics that are taught thus making mathematics unavoidable for some engineering faculty and their students. The lack of understanding of concepts in engineering mathematics may hinder the understanding of other concepts or even subjects. However, for most undergraduate engineering students, mathematics is one of the most difficult courses in their field of study.

Most of the engineering students never understood mathematics or they never liked it because it was too abstract for them and they could never relate to it. A right balance of application and concept based teaching can only fulfill the objectives of teaching mathematics to engineering students. It will surely improve and enhance their problem solving and creative thinking skills.

In this paper, some practical (informal) ways of making mathematics-teaching application based for the engineering students is discussed. An attempt is made to understand the present state of teaching mathematics in engineering colleges. The weaknesses and strengths of the current teaching approach are elaborated. Some of the causes of unpopularity of mathematics subject are analyzed and a few pragmatic suggestions have been made. Faculty in mathematics courses should spend more time discussing the applications as well as the conceptual underpinnings rather than focus solely on strategies and techniques to solve problems. They should also introduce more 'word' problems as these problems are commonly encountered in engineering courses. Overspecialization in engineering education should not occur at the expense of (or by diluting) mathematics and basic sciences. The role of engineering education is to provide the fundamental (basic) knowledge and to teach the students simple methodology of self-learning and self-development. All these issues would be better addressed if mathematics and engineering faculty join hands together to plan and design the learning experiences for the students who take their classes. When faculties stop competing against each other and start competing against the situation, they will perform better. Without creating any administrative hassles these suggestions can be used by any young inexperienced faculty of mathematics to inspire engineering students to learn engineering mathematics effectively.

***Keywords*—**Application based learning, conceptual learning, engineering mathematics, word problem.

I. Introduction

UNDOUBTEDLY, proficiency in mathematics is a fundamental necessity for any successful engineer in any era. The rapid pace of technological development constantly demands frequent updating from engineers in their field of interest. This may be being acquainted with the new technology and understanding of new technical concepts. Clarity and affinity with mathematics is an essential strong weapon in the armory of today's graduate engineers.

Mostly grown up educated people believe that mathematics is not taught properly in schools. The syllabus of mathematics in school is often far removed from reality. The syllabus expects (and compels) students to commit to rote learning or encourages them to adhere to methodology which kills the creativity and imagination, which is considered as a soul of mathematics. This also leads to students hating mathematics which further compounds the problem. From ages, mathematics has been perceived as a dry subject. From the first semester onwards, degree course students start losing interest in mathematics. This affects their performance in other courses also. Engineering students often develop negative mindset towards mathematics.

For variety of reasons, students do not achieve expected level of success. When asked about the reasons why they do not get interested in the subject or why they were not successful in learning mathematics, most of the students reply that they never understood mathematics or they never liked it because it was too abstract for them and they could never relate to it. This simply implies that Mathematics teaching has a crucial role in engineering education.

Any student joining engineering college in the first year is very excited and agog to have engineering experiences, (these students are bright, eager and motivated to learn) acquiring mathematics skills to experience this exciting engineering experience which is pushed to the background. The zeal to excel in engineering courses creates a mental blockade in the minds of students towards mathematics, and a hindrance in further learning as it becomes a secondary or unimportant subject. Faculty of mathematics and engineering courses should join hands to convey to students that mathematics is a language to understand engineering. Without mathematics, they cannot enjoy, feel and understand engineering.

The need of the hour is that more realistic and an effective approach to teaching of mathematics in schools and engineering colleges should be made, considering its importance in making truly powerful engineers.

Engineering students are not expected to perceive mathematics as professional mathematicians do, yet the professional engineer must acquire not only computational knowledge about mathematics but also abstract understanding of mathematics. A right balance of application and concept based teaching can only fulfill the objectives of teaching mathematics to engineering students. An abstract understanding of mathematics can be taught. It will surely improve their problem solving and creative thinking skills.

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Mathematics is always learnt sequentially and gradually layers of understanding are built over. For instance, topics of mathematics like algebra, trigonometry, differential calculus, integral calculus, and differential equations needs to be preferably studied in this particular order only.

Mathematics can be taught as a service subject, without causing any major impact on engineering students or it can taught by integrating with engineering subjects, such approach can develop a positive feeling in students for mathematics. It is believed that mathematical common sense derived in such type of application oriented problems is much more important than the mathematical rigor. Such approach of integrating mathematics knowledge with engineering can lay to rest the doubts in the mind about the importance of mathematics topics, which are taught in isolation [1], [2].

II. Adequate Emphasis on Word Problems in Engineering Mathematics

The essence of mathematics is the ability to simplify and solve problems in daily life. Mostly engineering students are known to find word problems difficult. By profession, engineers are problem solvers; they are hired specifically for their problem-solving skills. It is impossible to teach a standard approach that will always lead to a solution of a problem. Engineers use logic, science and common sense to solve problems. The easy and simple way of problem solving is to do it, thus engineering education should encourage students to solve variety of problems.

Engineers describe physical phenomena accurately with mathematical models. With the help of strong mathematics theorems and results the problem gets solved. With good understanding, critical-thinking and problem-solving skills word problems can be tackled. One has to read a word problem several times to understand it, unlike computational mathematics problems. Student has to understand the problem completely to figure out the solutions. Engineering mathematics courses does not deal much with word problems because they are very time consuming and sometimes they are given as project work. [2].

In a lifespan of an engineer, technology keeps changing dramatically. It is not possible for any professor to teach every fact (aspect) of it; today's state of the art technology becomes obsolete tomorrow. So to prepare tomorrow's engineer, we need to train their mind to think and solve problems. Mathematics plays very important role in this endeavor. These problem solving skills never become obsolete. Real world problems do not occur in the form of equations. Comparatively, word problems are closer to real world problems. The answers of real world problems are not given at the back of the textbook. The consequences of making a mistake in engineering are catastrophic. One of the most important skills in the armory of an engineer is the ability to estimate answers even from incomplete information. Rarely engineers get all the information required to precisely solve a problem. Mostly engineering problems are seen as an approximate or estimate problem. The degree of uncertainty is always very high.

III. Can Engineering Mathematics Be Taught in Isolation?

In India, traditionally engineering mathematics is taught as a separate subject in engineering courses. Mostly, the first semester courses of engineering mathematics are common for all engineering branches. The real problem starts from here; by isolating mathematics, engineering students finds it difficult to see mathematics as in context to their respective engineering branch. Thus if mathematics faculty do not give sufficient examples of respective branches to the students, the topic becomes irrelevant and isolated. Gradually many students lose relevance of learning mathematic. When students are treated as consumers or clients by the management of engineering institutes, management takes an active interest in ensuring that student's interests are met. The expectations of today's engineering students is changing, they are expecting to know (or to be told) immediately about the relevance of every topic that is taught in the class.

All engineering colleges are affiliated to some university and there is a common mathematics examination at the end of the first semester. Invariably students are prepared and taught courses keeping this common end semester examination in mind. More emphasis is laid in preparing the students to answer this examination well. For instance, Taylor and Maclaurin's series is taught to every engineering student in the first semester. Let us analyze how this topic is taught. Students are taught to find Taylor's series of various functions, without making them understand how and why it is important to study Taylor series. The concept of Taylor series is taught but actual relevant application of it is not taught. Students are taught only the computational aspect. More focus is on concepts and visualization [3]. In addition, as the first semester mathematics examination is common for students of all branches, a student of Civil engineering branch, perhaps never gets a chance to learn the application or relevance of engineering mathematics. Mostly branch specific applications of the topics are not taught. Leaving students confused about the relevance of learning the topic in their branch or discipline. As engineering students, they would like to see how mathematics is used to solve practical engineering problems, more specifically in their branch of engineering.

Taylor series is widely used in mathematics. It is well known that polynomial functions are easy to deal with, i.e. algebraic operations can be easily performed on them, and they can be easily differentiated and integrated. Taylor series can be used to represent a (complicated) function in a series form (infinite polynomial). This will help to study the properties of difficult functions. In addition, a very important fact should be kept in mind is that engineering students do not have much exposure to the branch of engineering until their second or third year. For example, Taylor series expansion could be used for error compensation in bi-axis CNC machines [4]. However, it is doubtful, if Mechanical engineering students can follow anything about the functioning of CNC machines in the first semester of engineering. The question arises, without having proper

background of engineering, how to teach relevant (branch specific) application of Taylor series to engineering students?

Differential Equations are the most useful topic of (Civil) engineering mathematics course. This topic being abstract and difficult to understand, many students struggle to do well in this topic. Differential equations describe the relationship between the rates of change in one variable compared to another. Differential equations arise in an attempt to describe or model physical phenomena in mathematical terms. Differential equations are used by Civil engineers to model a skyscraper's vibration in response to an earthquake to ensure a building meets required safety performance. The question is how a faculty of mathematics can give an application of differential equation relevant to Civil engineering when the students are ignorant about theory of vibrations and structure engineering in the first year of engineering?

Teaching common courses of mathematics to all branches of engineering is efficient from an administrative perspective but the pedagogical benefits to the students are debatable or questionable. Designing of mathematics syllabus tailored to a particular engineering branch is a distant dream.

It is important to note that our curriculum heavily emphasizes on teaching and learning through problem solving. Problem sheets are distributed each week and a number of selected questions are discussed in the following week during the tutorial session. The type of questions in the problem sheets ranges from simple to more challenging ones. The implemented teaching and tutorial sessions still rely heavily on the traditional method, where the faculty or instructor tends to dominate the entire teaching session. Although the students are also strongly encouraged to participate actively during the tutorial session, it remains a challenge to have an interactive teaching session, since many students are timid by nature [5].

IV. Variations in Teaching Methods

Two major aspects of teaching mathematics to engineering student's needs to be addressed what to teach, and who should teach engineering mathematics? In few engineering colleges, mathematics courses are offered and taught by branch or discipline specific faculty. Some of the engineering students feel that this way they can learn mathematics more comfortably and in a better way. Engineering students prefer the examples used to explain the various concepts of mathematics should be from their branch specific courses.

Usually mathematics in engineering colleges is taught by faculty from mathematics department, sometimes engineering faculty consider mathematics department as service department and treat mathematics faculty as outsiders. Many mathematics faculties dislike being called as faculty from service department. Conversely, if engineer colleagues teach mathematics, mathematics faculty looks down upon their capability. Teaching of any subject is not a monopoly of any department. A competent faculty with proper training and right aptitude can teach any subject but a faculty with specialization in the subject can do a better justice to it. Performance in the class should be the sole criteria to judge. Often a threat of mathematics subjects being taken over by engineering departments is also perceived by mathematics faculty. Due to this, an invisible divide gets created in the institution (The whole environment gets vitiated because of this) and gradually it is reflected in the students also vis a vis mathematics [5]. These glitches can easily arise where there is a lack of dialogue about mathematics teaching between engineering and mathematics departments, it can take the form of mutually supportive to hostile. The academic interaction between mathematics and engineering faculty is very poor. There is a need to bridge the gap that exists between them to improve the exchange of pedagogical and research ideas. Every engineering institute should have a platform or forum for discussion, disseminating and interchanging educational and pedagogical ideas between and among mathematics and engineering faculties. Guest lectures by engineering faculty should be arranged to reinforce the importance of mathematics in engineering and it will improve engineering student's appreciation of mathematics [6]. Also, engineering faculty can elaborate to the students about what mathematics is required to understand and do the engineering.

Imposing a very ambitious and vast syllabus of mathematics on students will not transform them into mathematics wizards. The vast syllabus kills the student's interest for mathematics and makes him more confused and averse to mathematics. Often engineering student lacks an understanding of the basic topics that are essential to follow a course. The only way out is to make our syllabus more realistic and compact. Breadth and depth both are vital aspects of mathematics curriculum but it is becoming difficult to achieve the right balance of them. While framing the curriculum of engineering mathematics, vital parameters like needs of engineering courses, industry needs, and lifelong learning should be given prime importance. To accommodate new topics, topics which are no longer of practical use or are taught in the earlier classes can be dispensed with (dropped).

All the educators of engineering education needs to change their strategy of teaching engineering as nature of both engineering profession and student joining engineering colleges in the 21st century is changing. In addition, requirement of the industry (Engineering & Technology based as well as Software based industries) recruiting majority of these engineering students is changing, industry prefers directly deployable student in the industry with management and communication subjects in the curriculum. How to implement these changes without diluting the engineering curriculum has become an open ended problem worldwide for the educators. Some institutes reduce the mathematical content in the curriculum to cater the industry needs. There is always a difficulty of reaching a common understanding between mathematics and engineering departments about how much mathematics to be included in the curriculum and what topics to be taught. Overspecialization in engineering education should not occur at the expense of mathematics and basic sciences [7], [8]. Sometimes a dispute may also occur about whether a course should be taught by a problem based or project based method, these terms are often used interchangeably. Problem based learning is more focused

towards acquisition of knowledge, whereas project based learning is focused towards application of knowledge. Mostly in engineering subjects, it is difficult to differentiate between problems based or project based subjects as most of the subjects contain elements of both. Project based learning allow students to put into action the knowledge acquired in the foundation courses to solve real world problems. To solve these problems new knowledge is also required. In engineering colleges, students are very receptive and use these approaches to understand or learn any new subject by solving a real world problem. Use of problem based or project based approach in mathematics will allow students to develop communication skills, team work, research skills and an appreciation of the inter-disciplinary nature of mathematics [9], [10].

V. Conclusion

To be a successful professional engineer in future, engineering students should have a good grounding in mathematics and science. We should bear in mind that solid foundation of mathematics and science is also a step in the right direction for lifelong learning. The close liaison between mathematics and engineering departments can play a vital role in this effort. To enable greater student understanding, let all mathematics in engineering be taught by mathematics department using branch specific engineering examples and problems, help in this effort can be sought from the various engineering departments. The objective is to teach the students examples that are relevant to their branch of engineering to help them in understanding the concepts and its utility. Students will start feeling attachment with mathematics if they see the relevance of what they are doing with mathematics, thus it will motivate them to take mathematics more seriously. Collaborative teaching should be encouraged; inter-department rivalry should not hamper the teaching. Some trained engineering faculty can teach engineering mathematics courses and some mathematics faculty can teach engineering courses like Mechanics, Dynamics, Statics, Fluid Mechanics, Signal Processing, etc. Success in mathematics often raises a confidence and leads to positive attitude resulting in more success. We should motivate and encourage engineering students in doing mathematics.

We should always remember that if a student with an average intelligence does not understand a concept of any subject after making good number of attempts, we should not doubt his ability, the other possibility that a faculty or a book or textbook has not given a good explanation and illustration of the concept could be true. Sometimes mathematics becomes difficult to understand because the concepts are explained in terms of some other concepts.

Engineering education in different countries has been developed with different traditions, making it difficult to choose the best model for all. The role of engineering education is to provide the fundamental (basic) knowledge and to teach the students basic methodology of self-learning and self-development.

Deep mathematical understanding is a basic requirement in today's engineering student. To gain such understanding first we need to identify what mathematical skills are required and where in the engineering curriculum these skills are applied. This exercise will only bridge the gap between mathematics and engineering.

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