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REINVENTING THE TEACHING OF ENGINEERING WITH TECHNOLOGICAL SOFTWARE: CURRENT ISSUES AND TRENDS

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ABSTRACT

Teaching in the subject of engineering mechanics dynamics deserves significant attention. Since this subject relies heavily on the combination of mathematics, free body diagrams and the effect of forces, many students are facing difficulty in visualizing the engineering concepts in general. While much research and various approaches have been employed by researches in the past to overcome this dilemma, not much has improved this situation. This paper review problems faced by students in the subject matter, approaches used in enhancing the learning process and suggest how technological software could be used to help students in solving selected engineering problems.

Keywords: Education, Engineering, Technology, Software.

1. INTRODUCTION

Education is a combination of multiple processes, these can be defined as teaching processes and learning processes, with its main objective to help students acquire the knowledge needed, to be used in future (Zhao, 2005). Dobson (2012) reports that the number of enrolments in undergraduate programmes in engineering has grown at more than the national average this century in Australia. However deep problems and issues in teaching engineering courses have persisted for the last two decades. Many studies have been done to answer this dilemma, in order to provide the labour market's demand for engineers who are not only knowledgeable but also technically competent.

Approaches like Problem-Based Learning (PBL), Computer Aided Learning (CAL), active learning, cooperative learning and team-based learning (QingWei and Yu, 2013) are among the ones that have been widely used in teaching engineering courses to improve the learning process of undergraduates, but unfortunately not much has improved in this state of affair. Most engineering graduates are equipped with theory and facts (Direito et al., 2012), but incapable of visualizing the engineering concepts in general and relating this concepts learnt to the industry which one in after graduation. Therefore it is important that the teaching of the subject of engineering mechanics dynamics addresses the issue of engineering education in order to meet the expectation of stakeholders.

To attend to the matter mentioned above, the problems and challenges faced by 3rd year engineering students at UNITEN will be discussed foremost in the paper, to give an overview of what is standing in between students and their goal in understanding engineering mechanics dynamics subjects. Among many approaches that have been used in the past to enhance the learning process, two selected approaches will be discussed in the later section of this paper, and followed by the suggestion on how technological software with graphical interface could play a part in assisting students to solve the selected problem in mechanical engineering courses.

2. PROBLEM ENCOUNTERED BY STUDENTS

Students embarking on their 3rd year mechanical engineering program will be exposed to classes on machinery design which revolves heavily around the combination of mathematics, free body diagrams, effect of forces and may even undergo evaluation on effective solution to meet social needs. This has found to present substantial challenges to students. Hence, the discussion here will focus mainly on the problems that arose among students in the advanced mechanics subjects.

An interview was conducted with two lecturers in UNITEN who have thought and are currently still teaching the Machinery Design subject. The problems encountered by students in class based on the observation of the lecturers are listed as below in Table 1.

Table- 1. Problem in learning the subject matter by engineering students

Problem in learning the subject matter by engineering students
• There are too many formulas and parameters involved for mathematical calculation which students are confused with.
• Students are unable to visualize the changes to each parameters involved and evaluate the effect accordingly.
• Students have difficulties in understanding the questions and extracting information from it.
• Students are lack of interest in reading content and explanation from textbook for better understanding of the subject matter.
• Students face difficulties in relating the concept learnt with other domains out of context.
• Students have a weak foundation in the previous subjects that relate to Machinery Design.
• Students are lacking in confidence in making assumption during problem solving.

With the lecturer's observations on the responses received form students on the subject matter, the problem and challenges encountered can be streamlined into three categories, as follows:

2.1. Ability to Spatial Visualize

Spatial visualization is the ability to convert spatial information into pictorial representation and manipulating the design in their imagination, to be understood by the brain in the learning process (Crown, 2001; Sorby, 1999). This ability enables engineers to conceptualize relationships between reality and the theoretical model of the reality (Alias, et al., 2002), which is helpful especially in the learning process of machinery design in mechanics dynamics subjects that involves heavily on manipulating the design before applying it for production.

For example, the analysis of bending stress in gearbox design, the gear model is the reality, as the stress distribution, effect of one parameter on to the others are among the theoretical model that require the visualization skill mentioned. In designing a gearbox, students are required to have a thorough understanding of the subject beforehand, especially the relationship between each parameter involved in the formula used, so that they can make suitable assumptions like the materials used, "shockiness" of the machinery, and quality index of the gear set, to identify the bending stress analysis of the gearbox. Students that are equipped with the visualization skill will have the advantage in computing and identifying the stress distribution easily, as they can relate the reality and the theoretical model in mind before putting the values into the formula for design.

Studies have shown the important of spatial visualization in education particularly in the field of engineering, it also influences the academic performance in engineering too. According to the research work done by Crown (2001), students are at risk of not passing the engineering design courses if they scored below average in the three dimensional spatial perception tests. Hence it is clear that the ability in spatial visualization is vital in the learning process of machinery design in mechanics dynamics.

2.2. Ability to Make Assumption

One of the challenges in mechanics dynamics subjects is the ability to make assumption of the details as the system or machinery expands, which comprise of more variables and parameters. In machinery design one formula may consist of multiple parameters, so to excel in it, students have to effectively identify the manipulative parameters and safely neglect the constant in achieving a cost effective design.

In the study conducted by Linder (Linder, 1999), as quoted below, shows that the estimation skill is vital in engineering education and it could affect the ability in solving the common engineering problems.

"Students were found to have considerable difficulty making estimates for common engineering quantities, such as force and energy. Students were also found to have difficulty applying basic engineering concepts in rough estimation situations even at the senior level."

At the University of Pacific, an impromptu survey was distributed to 58 graduating seniors in engineering major. The author finds that the result is a match with the finding by Linder, that engineering students are inadequate in making estimation even on the simplest estimation problem (Shakerin, 2006).

In the case of analyzing the stress distribution of the gear, only one formula (1) is used to compute the bending stress of the machinery. However, there are 10 variables that are inter-related in the formula and in most problems, only 4 to 5 values will be given in the question and students have to make estimations for the rest to solve the ill-defined problem.

$$\sigma_b = [(W_t P_d) / (F\ J)]\ [(K_a K_m) / K_v]\ K_s\ K_B\ K_I \quad (1)$$

σ_b	:	Bending Stress	K_m	:	Load Distribution Factor
W_t	:	Tangential Force on the Tooth	K_v	:	Dynamic Factor
P_d	:	Diametral Pitch	K_s	:	Size Factor
F	:	Face Width	K_B	:	Rim Thickness Factor
J	:	Bending Geometry Factor	K_I	:	Idler Factor
K_a	:	Application Factor			

The dilemma arises when students are unable to use estimation to determine the feasibility of the idea and anticipate the unintended consequences emerging from the combination of the estimations, before implementing it in the machinery design. Studies have shown that even students in the senior year require help with the estimation to solve the problem effectively (DYM et al., 2005; Linder, 1999). Engineering teaching method and curricular design should always be revised, such as employing technological software in teaching to improve the critical thinking of students in making estimations based on the knowledge in engineering and science. This matter will be discussed in section 4.

3. ABILITY TO UNDERSTAND

The key to excel in a subject matter is by understanding it out-and-out. It is to be known that engineering subjects involve heavily with concepts, theories and formulas that are needed to solve the problems. Most students are manipulating the equations to solve problems instead of gaining the conceptual understanding of the subject matter, as they are unable to comprehend how the knowledge is structured (Ellis & Turner, 2003). With such an approach in learning, students will not be able to apply their knowledge to other domains outside of the textbook.

Although students will be given numerous of exercises or problems to be solved in lectures, to ensure they understand the subject matter, but little do we know that most of the students are just following the instruction in solving the problem without a complete grasp of the topic. This becomes clear when they are unable to solve the problem when it is asked differently than the ones in their exercises and instructions (Ellis et al., 2004), similarly as applying their knowledge in other domains.

Besides that, understanding the questions is equally important too. Even students who have a complete understanding of the subject matter, they too could face problems in extracting information from the question while in the midst of solving it. According to the interview conducted with lecturers from UNITEN, some students are unmotivated in reading the textbook to comprehend the question’s requirement properly, they would just extract figure from part of the question without understanding the question as a whole. Hence this will eventually lead to poor academic performance in the subject, simply due to the vague understanding of the problem’s requirement and subject matter.

3.1. Approaches to Enhance the Learning Process

Researchers have always been keen on studying student’s learning process, with the goal to enhance the learning process of students, ensuring there is long-term retention of knowledge compared to the traditional learning method. Throughout the years, variety of learning approaches have been developed and implemented in the field of engineering education, like Problem-Based Learning (PBL), Computer Aided Learning (CAL), active learning, cooperative learning, concept maps and many more.

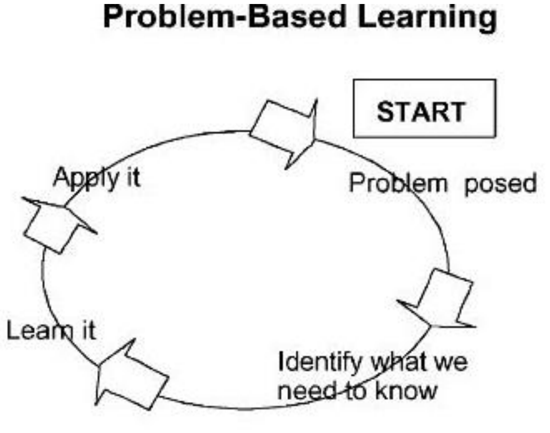
Among many approaches, PBL and CAL that have been widely employed in teaching and learning will be discussed in the next section.

3.2. Problem-Based Learning (PBL)

Problem-Based learning is an instructional learning process of presenting an open-ended, ill-structured, real-world problem to a group of students who will be working as a team in developing solutions to the questions. In such situation, the lecturer will act as a facilitator in guiding them rather than spoon-feeding them with the complete solution (Prince, 2004). The problems are usually based on the real-life issues so that the learning content can be easily related to its context (Graaff&Kolmos, 2003), which eventually makes the learning process effortless.

Although PBL approaches have been implemented into the education system, it varies according to the institution’s educational objective and criteria, but the process of PBL are generally the same. PBL approach can be depicted in Figure 2 by Woods (Smith et al., 2005).

Figure-1. Process of Problem-Based Learning



The PBL was first implemented in a medicine program at McMaster University in Hamilton (Smith et al., 2005). As its result suggested improvement in student’s learning process, then it started to be employed into other education programs, like engineering (Krishnan &Yassin, 2009) and computer science (O’Grady, 2012).

With the implementation of PBL approach, students are more motivated and hardworking as compared to the traditional method (Graaff&Kolmos, 2003), because of the open-ended problem enables students to uncover different approaches in solving the problem and this creates a better understanding through the process of problem solving. Besides that, the analytical skill of students is expected to be improved, with multiple approaches in problem solving. For an engineering student, the analytical skill is rather essential to excel in design related subjects, because there will be multiple ways to design the machinery. And among all the choices, students are required to evaluate and come out with the most cost effective design, which is one of the weaknesses in engineering students as explained in the earlier section.

In spite of the effectiveness of PBL approach, it is still not widely practiced in the engineering classroom as loads of preparation works is needed to be done beforehand and faculty members are not exposed to any PBL during their undergraduate education (Akili, 2011; Smith et al., 2005). Hence, it is difficult for them to conduct classes with an approach that they are unfamiliar with.

3.3. Computer Aided Learning (CAL)

With the growth of technology in our lives, the computer has come to play an important part in our learning process too, which is better known as Computer-Aided Learning (CAL). CAL is the involvement of technology in the teaching and learning process, by means of integrating computer software into the learning environment.

From the perspective of a learner, CAL has a more interactive and motivating setting compared to the traditional lecture, especially to engineering students which favor the active experimental learning style as stated in (Felder & Silverman, 1988). In another study by Neumann, Neumann and Hood (Neumann et al., 2011), indicated a positive learning experience by students, and they are more interested and motivated too. By building up the interest among students on the subject matter, they will be keen in acquiring more knowledge with the deep approach (exploring and understanding in and out of the new material) towards it, rather than a surface approach (rely on memorization and substitution of the formula, with a vague understanding of the new material) (Prince & Felder, 2006) which is merely memorizing and recalling the theories in engineering subjects. The result is also confirmed by Lowe, Wright, Bearn (Lowe et al., 2001), the implementation of CAL is a cost-effective way of imparting knowledge and has demonstrated a definite place in teaching the subject.

Nevertheless, there are still lecturers that prefer the traditional approach in teaching as they are skeptical in doing things out of the box (Ho et al., 2002). Some senior lecturers are taught in the traditional approach which is the textbook, hands-out and verbal explanation in class. As such CAL is to be considered as an alternative approach to them. And due to the unfamiliarity with the use of computer and the interest in learning new gadgets, they are reluctant to employ CAL in their class, although a good CAL material is able to capture the attention and interest of user, and as well as to teach effectively in class.

3.4. Team Based Learning

Taking team-based learning as the foundation, the mature and available teaching schemes cover team grouping, evaluation, team-based classroom teaching, group activity planning and other aspects. (QingWei& Yu, 2013). They further explained that team-based learning requires instructors to organize teaching content around knowledge points. It should take 10-15 minutes for an instructor to teach each knowledge point, which can give students a sense of constant freshness and renewal. The content of each knowledge point should cover principles, any relevant algorithm, a demonstration, examples and two-to-three questions related to the content of each knowledge point for team discussion. The goal of team discussion is to carry out self-learning within the team and to digest the material just taught. However, implementing a team-teaching approach requires administrative encouragement, acceptance that the initial quality may be adversely affected because of the experimental nature of the approach and a willingness to take risks.

4. HOW TECHNOLOGICAL SOFTWARE COULD BE USED

As mentioned above, engineering programs are to be known with numerous theories, concepts and motion of forces which students find it as a challenge to understand. Although previous approaches used have shown improvement in the learning process, unfortunately it is very little, and some are rather time-consuming for the result to take place. A change of the paradigm in delivering the knowledge by the aid of technological software has been proposed as a solution to the difficulties faced by students in the subject matter. Technological software is a program or software tool that is implemented and to be used in computer according to one's preference, and now it has been widely used especially in the educational field. Hence, the next section presents how the technological software could be used to deal with the problem stated above.

4.1. Process in Action

As an engineering student, it is very important to understand the motion of the forces for example, how does one affect another directly or indirectly in the machinery design; so that it can be taken into account in the designing process and they can anticipate the unintended consequences that come along with the interaction among multiple parts of the machinery. As suggested in (DYM et al., 2005), the use of modern computational tools is proposed as an alternative solution to the subject matter, and as well as to support the probabilistic thinking of students too.

Computational tools such as the technological software which has the characteristic of interactive learning, making learning process much more effective, as students are allowed to interact with the program and receive instant feedback or response given by the program to evaluate the student's answer. It also has the ability to portray the whole force motion and interaction with images or simple animation, so students can see the "big picture" of the concept and boost their motivation to take a deep approach in studies too. As for engineering students, the technological software enables them to convert their design ideas into motion, which is difficult to perform in real machines. For example, if a machinery design's formula contains numerous variables, students are unsure with the assumptions they have made in the designing process, they can apply the trial and error approach in learning by manipulating the variables in the software and re-run the program to test the results until they come across with the most cost-effective solution. This whole process of problem solving takes up no cost at all and students are given the freedom to experiment as much as they prefer.

With the process in action, most engineering students which favor the visual learning method (Felder & Silverman, 1988) can benefit the most out of it, through the visual representation of the concept. It can also facilitate traditional lectures that engage only the verbal teaching method in class. As such, having the process in action is making the teaching and learning to be carried out effortlessly.

4.2. Easily Accessible Learning Tool

Setting appointments with lecturers sometimes is troublesome due to the lecturer's busy schedule and the number of students they have to attend to. As such, students will be unmotivated and resort to either skipping the topic that they have problems with or just apply a surface approach in understanding it, which will result in a poor academic performance in problem-solving.

On the other hand, the easily accessible technological software is a learning tool that is able to tackle the problem stated (Shuman et al., 2002). It can be installed in any computer either in the lab or at home and students are able to access it anytime, without any time constraint. The freedom of time enables students to perform learning with their own pace and timing, when they are prepared and motivated to do so.

The easily accessible learning tool does not limit the students to be at a specific location to study, it promotes distance education too. Part time students can obtain quality education anywhere without giving up their career and family. On top of that, travelling to the university or college is omitted when technological software can be easily accessible for learning at home.

4.3. Personal Attention

In the process of learning, every individual varies accordingly to their own pace and preference. Hence, the learning should be tailored to the individual so they can benefit the most out of it. However, most varsities apply the traditional teaching method, which is having one lecturer attending to sixty over students in a single lecture hall. Such constrain creates difficulties for students to get the attention from the lecturer if they encounter problems in understanding the topic. However, technology can accomplish the optimal condition of learning and teaching (Shuman et al., 2002), as it provides one to one interaction to students.

The technological software allows students to interact and experiment with the program personally without any time constrain. For weaker students that struggle to understand the subject matter, like more time is required for them to digest the content thoroughly, they can easily read the slides or watch the video repeatedly until they understand it clearly. The personal explanation and video playing does not interrupt the learning process of the other students in class, but also help the weaker ones by giving them personal attention on the subject matter.

4. CONCLUSION

The paper has explored on the problems encountered by UNITEN's engineering students in their learning process. It shows that the problem can be streamlined into three different categories which is (a) ability to spatial visualized, (b) ability to make assumption and (c) ability to understand. With the lack of such abilities, it will create a dilemma for engineering students in employing their knowledge to other domains.

Past approaches used have not showed much improvement in the matter. Therefore technological software is suggested to be employed to the teaching and learning process due to the advantage of having the process in action so student will have a better grasp of the topic with visual representation of it, and it gives students personal attention which is easily accessible at anywhere and anytime.

In summary, this paper has showed, it is a call for all educators particularly in engineering programs to not only educate students with all the facts and theory to excel in their studies but also to ensure that the learning process is conducted effectively, so that engineering graduates are academically and technically competent.

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