

The Pedagogical Issues in Engineering Statics

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Abstract: A study on students' performance at an engineering department in a government-funded university in Malaysia revealed that the percentage of students not graduating on time and failed to graduate is high for a particular engineering program as compared to the other programs. A deeper study lead to one of the contributing factors, which is the poor students' performance in their first year. Further investigation revealed that Statics, which students took as their first engineering course, has the highest failure rate. There are several cases where students had to repeat the course three times before obtaining a pass to be able to move on to the follow-on courses. This paper examines the pedagogical issues facing the teaching and learning of Statics in the case of this engineering department. The **teaching approach** of Statics and students **learning difficulties** in the course are discussed. This is compared with current trends and research findings in the same area worldwide. The findings in this paper would be useful for stakeholders involved in the design and development of this fundamental course.

1 INTRODUCTION

A study on students' performance at an engineering department in a government-funded university in Malaysia revealed that the percentage of students not graduating on time and failed to graduate is high for a particular engineering program as compared to the other programs. A deeper study lead to one of the contributing factors, which is the poor students' performance in their first year. Further investigation revealed that Statics, which students took as their first engineering course, has the highest failure rate.

In mechanical, civil and electrical engineering at many higher education institutions, Statics is typically the first engineering course that students encounter. Statics is a fundamental course in engineering and a pre-requisite to other core engineering courses like Dynamics, Fluid Mechanics, Solid Mechanics, Mechanics of materials, Machine Mechanics and Design.

Statics is normally offered in the first year as the first Mechanics course of which is part of three distinct areas namely: mechanics of rigid bodies (subdivided into Statics and Dynamics), mechanics of deformable bodies, and mechanics of fluids.

1.1 Statics

Statics deals with bodies at rest. In Statics the conditions of rest or motion of particles and rigid bodies are studied in terms of four basic concepts; space, time, mass, and force. Typical topics covered in Statics are two- and three-dimensional systems of particles and rigid bodies in static equilibrium using vector approach. Other topics include concentrated and distributed forces, centres of gravity and centroids, and moments of inertia. Special attention is usually devoted to forces in frames, structures, beams, and cables.

Statics problems are often concern with multiple bodies that must be dismembered; rotations of bodies which have finite

dimensions; and determination of force directions with forces that can be multiple and distributed between bodies. Steif (2004) claimed in his paper that a number of mathematical skills which include the summation and decomposition of forces and the calculation of moments are critical to solving Statics problems. Mathematical knowledge like algebra, trigonometry and elementary calculus has been identified as pre-requisite for Statics.

Prior knowledge in Physics Newtonian mechanics, such as the Principles of Newton's law serves as the basis for understanding Statics concepts. However, due to the complexities of Statics over Physics, Statics demand a significantly enhanced understanding of the same fundamental concepts such as of force and equilibrium (Dollar & Steif, 2004).

Deeper understanding of key concepts in Statics is needed to succeed in the follow-on courses. The concepts and engineering principles in Statics are the foundation of the concept building blocks that students must comprehend to enable them to succeed in their engineering program.

Literatures have indicated that Statics is a course that many students have difficulty in, especially in understanding the challenging concepts that continually build upon one another in increasing complexity (Chen, Kadlowec, & Whittinghill, 2004; Dollár & Steif, 2007; Haik, 1999). The difficulties in this fundamental engineering course have often resulted in poor performance not only in Statics but also in the follow-on courses (Dollar & Steif, 2004; Sidhu & Ramesh, 2006), thus, often discouraged students to pursue engineering as a career (Sidhu & Ramesh, 2006).

I would emphasize that students all over the world have trouble with Statics, including at the very best universities in the US (and with great lecturers). That some impediments to learning are universal (hard concepts) and others have to do with the local culture and work habit of students.

(P. Steif, 2008)

2 PEDAGOGICAL ISSUES

The need to study the challenges faced by the engineering department described in the introduction is of paramount importance.

Data from as far back as semester 1 of academic session 2003-2004 showed the percentage of students' failure in Statics is high comparing to other courses taken in the same semesters. The average percentage of students who fail Statics from that semester to semester 2 of session 2007-2008 is about 22 percent per semester, with the highest record of 46 percent and the lowest of 13 percent (Fig.1). There are several cases where students had to repeat the course three times before obtaining a pass to be able to move on to the follow-on courses. There are also students currently taking Statics for the fourth time. Several cases led students to withdraw from the program as a consequence of the extension period. This statistic calls for an investigation as to the contributing factors to the poor performance.

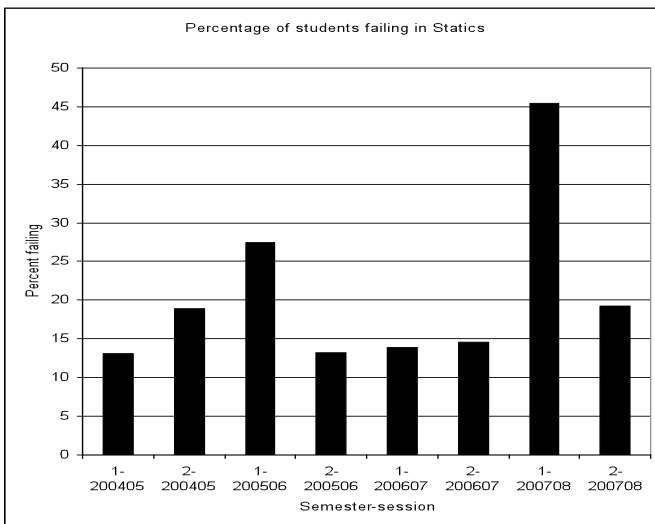


Fig.1. Percentage of students failing Statics per semester.

2.1 A Preliminary Study

A preliminary study was carried out at the particular engineering department. Observations were made at two Statics classes that were offered in semester 2 of the academic year 2007-2008 with a 109 total number of students enrolled. Another observation was carried out in semester 1 session 2008-2009 at the only class offered that semester. There were only 18 students with the majority repeating the course. Students in the class were also interviewed to get some feedbacks on their experience learning Statics.

Questionnaires were distributed to a sample of 200 second- and third-year students of the particular engineering program to gain an understanding of their learning strategies in Statics and their previous experiences attending Statics class/es.

2.2 Challenges in Statics

Figure 2 shows some of the challenges students face in learning Statics as found in the literature reviews and derived from the preliminary study. The challenges can be divided into three categories related to students' factor, teaching approach and nature of the course. These are elaborated further in the following sub-sections.

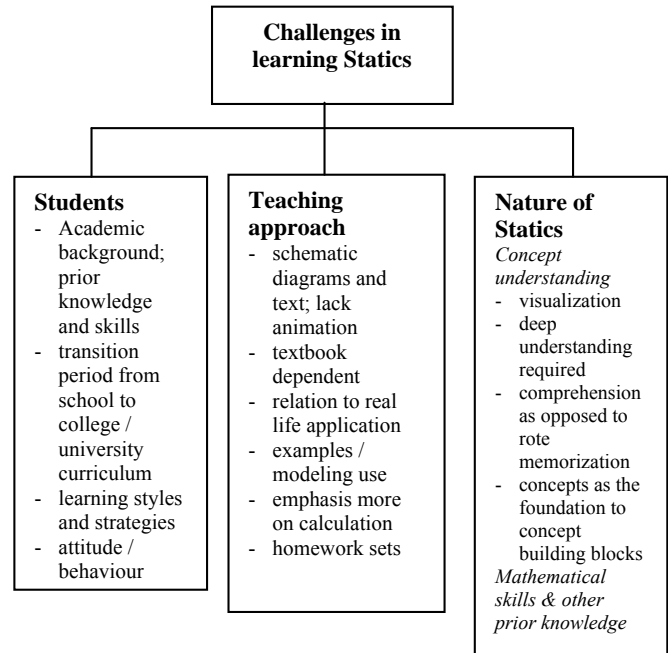


Fig.2. Challenges in learning Statics.

2.1.1 Students

(i) Academic background, prior knowledge and skills

Students at the engineering department under study varied in terms of their academic background. Whilst the majority of students enter the department after *Sijil Pelajaran Malaysia* (SPM), there are some who entered from polytechnics and a few from matriculation centres.

Analysis of entry results for Physics and Mathematics of students who joined after SPM and had failed Statics from semester 1 2004-2005 to semester 2 2007-2008 showed that about 92% of them came in with credits above 3 in Physics and 89% for Additional Mathematics.

Students' results in courses like first year Trigonometry and Physics which should also provide basic skills and knowledge required in Statics were also looked at. 86% got grades C+ and below for Trigonometry and 90% for first year Physics. However, students coming in from polytechnics were given transfer credits for their Physics and Trigonometry (some of these students had been identified as repeaters for more than 3 times).

It has been observed that students' grades in Statics pre-requisite courses like Mathematics and Physics do contribute to the factors that affect students' performance in Statics. Bowen, Prior et al. (2007) mentioned that the Quality Assurance Agency (QAA) course report for Mechanical, Aeronautical and Manufacturing Engineering stated that failure is common due to difficulties in mathematical skills and that mathematical problems exist in all engineering courses. According to the report there are evidence of a decline in the mathematical capabilities of entrants onto engineering programs and diversity in mathematical knowledge among the student population. Mathematics has been identified as an area of concern for engineering (Bowen, Prior, Lloyd, Thomas, & Newman-Ford, 2007).

(ii) Transition period, learning culture, behaviour

Students interviewed indicated that the transition period from school to university curriculum was a factor for their poor performance in Statics. Apart from Statics being the first

engineering course they encountered in the program, the learning and teaching approaches were significantly different from what they experienced before. The learning *culture* now is different in many ways which include the need for less rote memorization and more independence in their effort to study. However, learning to pass examinations has been the main agenda from when they were in schools.

The teaching approach differs especially in terms of the independence expected on the part of the students by the lecturers. The lecturers expect the students to be proactive in seeking more information on the courses taught and in communicating their ideas, thoughts and questions.

Those who had gone through the course several times indicated that they had put a mental block to learning Statics.

Observations in two classes in semester 2 of the academic year 2007-2008 showed the same pattern of students' *behaviour*. It was observed that only about 10 percent were involved in class activity, attempting to solve the problems given on the white board. The other 90 percent were passive, did not make any attempt to solve the problems given but appeared to be waiting for the lecturer to provide the solutions or waiting for the next activity. About 10 percent of these students appeared to be uninterested, not even copying solutions, but in their own world, throughout the class session. Towards the end of the period students were already noisy with own conversation. They paid attention when tips on the coming test were given.

Those students who appeared to just sit and stare unresponsively may be assumed to be uninterested as they hurriedly left the class at the end of class period. It is also possible to assume that those who were passive are those who had previously taken the course. There were about 27 percent of the students who enrolled that semester who are repeaters, with some of them taking the course the third time.

In semester 1 of the academic year 2008-2009, it was observed that although some students appeared stuck, most of them were engaged in attempting to solve the problems and appeared to be motivated to do it. Three students interviewed admitted that they gained more confidence after taking Statics the first time. They admitted to understand the course better this time due to the teaching approach that is with 'more personalized' attention given by the lecturer.

2.1.2 Teaching Approach and Nature of Statics

(i) Observations

It was observed in both semesters that classes were taught in a traditional, face-to-face approach. The only teaching aid in use was the white board and a text book. The classes were taught by a different lecturer for each semester.

In semester 2 of the academic year 2007-2008 it was observed that the lecturer started the class by giving verbal explanations on the topic that was to be covered during the class period. Almost all of the students were unaware that the lecturer had started to speak until after almost five minutes. The students took time to settle down as most of them had a class prior to Statics.

The lecturer then moved on to show the procedure to solve a related textbook problem on the whiteboard. He would continue writing until the board was full, and then rub off the earlier section to continue writing the rest of the solution.

The students then were asked to solve several textbook problems in class. In one of the classes students were asked to volunteer to solve the problems on the whiteboard, but when no one volunteered, the lecturer had to call a name at random from

the attendance list. In the other class, the lecturer gave some time for the students to attempt the problems on their own before working through it on the whiteboard.

In semester 1 of the academic year 2008-2009, the lecturer was observed to interact a lot more with the students. Students were guided on how to approach Statics problems from the textbook. They were given time to solve the problems on their own before being asked to share their answers. The lecturer was observed to check on students' work while they are still working on the problems. The students were given personal attention. This is made possible with the small number of students attending the class.

Both teaching approaches focused on the mathematical derivations of the textbook problems and emphasis was on the problem-solving procedures. It has been observed to engage students as a class activity. However, at the same time the lengthy mathematical derivations are recognized to be a barrier for students to grasp the concepts in Statics. There was lack of emphasis on conceptual understanding and practical application during the periods observed. Students unable to relate Statics to real life situation is recognized as students lacking the adequate skills to implement those concepts, thus, pose a difficulty in Statics (Dollar & Steif, 2004).

Learning principles were not adopted, for instance in identifying students' preconception and in engaging students' learning. There seem to be no opportunity for the students to reflect and digest information during the class period as the students were mostly busy copying solutions from the whiteboard.

Figure 3 below shows the summary of factors affecting students' performance in the department.

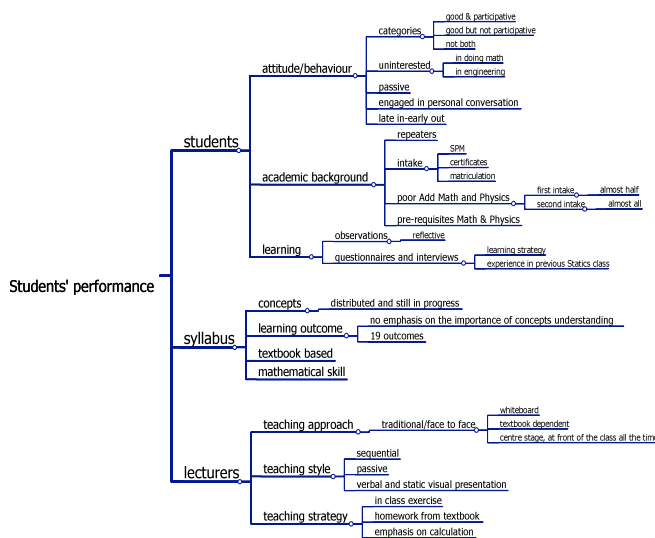


Fig.3. Factors contributing to students' performance.

(ii) Literatures

In most institutions, Statics is taught with an emphasis on the mathematical operations that are useful in its implementation. This approach is normally without enough emphasis on modeling the interactions between real mechanical artifacts (Dollár & Steif, 2007). As a result, students face difficulties such as the lack of ability to translate mathematical equations into the form necessary for effective computation. Lengthy mathematical

derivations in solving some Statics problems usually cause students to be de-motivated.

....lengthy mathematical derivations that lead to the principle of design for machine elements cause students to be de-motivated because they are unable to neither connect to real life nor express their creativity.

....students become more motivated and even willing to deal with long mathematical derivations and difficult problems only when they realize the importance of machine design course in the real life of a mechanical engineer, and the limitations of their knowledge.

(Khoshaba & Shrivastas, 2004)

In general, engineering problems in textbooks are presented by diagrams and figures shown in a static form (not animated). The problems are often complex, and the relationships among variables of an experiment could also be difficult to visualize.

Engineering mechanics courses are fundamentally about problem solving through the application of scientific principles. In solving the problems, students are required to apply learned knowledge to form an internal model of the problem, failing which often result in lack of interest in the course content. Course content and problems are presented in the textbooks as a combination of non-animated schematic diagrams and text descriptions. The problems in Statics are often complex, and the variables are normally difficult to **visualize**. Students find it difficult to solve the problems they cannot visualize. They become de-motivated to learn when they are unable to relate to real life situations.

Other challenging factors that contribute to difficulty in learning Statics include the realities of the rapid pace of materials presented, the steady succession of homework sets, and the self-discipline required to complete them.

2.3 Current Trends

Teaching practices has transformed from teacher-centered to student-centered, where students themselves are responsible to gather knowledge and make sense of it. The approaches to teaching and learning of Statics in many engineering schools have been designed to accommodate a variety of learning styles, and to adopt different learning strategies and theories.

Blended learning, where technology is used together with traditional means, has also been introduced in engineering classes. As described in the literatures, multimedia courseware, online or web-based materials, and classroom activities which include the use of mechanical artifacts, have enriched the learning process in many ways. Motivation to learn, engagement in learning, and better understanding of the course are some of the positive outcomes quoted. Several teaching approaches of Statics are summarized in Figure 4 below. These examples are briefly listed below:

Technology-based include:

web-based, on-line courses

- in-class / out-of-class
- animated
- 2D
- 3D -> virtual reality

multimedia coursewares

- in-class / out-of-class
- games

- 2D

- 3D

blended

- integrating traditional and technology-based approaches (Beston, 1999; Dollar & Steif, 2005; Dollár & Steif, 2007; Dollár, Steif, & Strader, 2007; Holzer & Andruet, 2000; Hubing et al., 2002; Oglesby, Carney, Prissofsky, & Crites; Sidhu & Ramesh, 2006)

Design-based, integrated:

Statics is integrated with related courses such as Dynamics, offered as Mechanics, or integrated with Mechanics of Materials, or included as part of design-based courses. (Haik, 1999; Holzer & Andruet, 2000)

Games

Concepts and problems presented in games format. (Chan & Black, 2006; Philpot, Hall, Hubing, & Flori, 2005)

Face-to-face

Using mechanical artifacts / physical model, whiteboard, PowerPoint presentation, Learning modules, PBL and active-cooperative learning.

(Holzer & Andruet, 2000; Mehta & Danielson, 1999; P. S. Steif & Dollar, 2003)

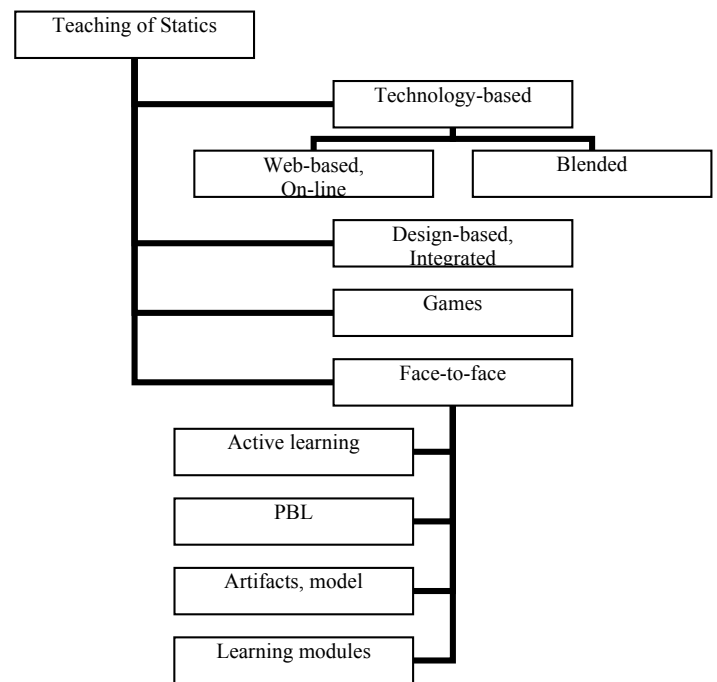


Fig.4. Current trends in teaching and learning.

3 CONCLUSION

From this preliminary study the authors identified several key challenges in the teaching and learning (T&L) of Statics. These challenges seemed to be universal and can be summarized as below:

- Deep understanding is required but rote memorization is '2nd nature' to most students. Their learning culture is still towards learning to pass the examinations. Thus, drill and practice is widely adopted by not only the students but the lecturers as well.

- Mathematical skills are required but entrant qualification seems to be degrading.
- Prior knowledge in Physics is not sufficient for learning and grasping the concepts in Statics.
- Practical applications are needed to grasp concepts but there is a lack of implementation or usage of models, artifacts and animation which could help students to visualize and make connections between the concepts and real world application.
- Traditional face to face and whiteboard approach is still practiced, although many efforts have gone towards developing technology-based teaching and learning.

Facilities and support from the department, incentives, know-how in the use of technology, and knowledge in learning theories & principles are some factors that seem to hinder the transformation of T&L, especially on the part of the lecturers. From lecturers' interviews, first reason for poor students' performance in Statics given by the lecturers is students' behaviour. Meanwhile, from the questionnaire distributed and several interviews, majority of the students is in the opinion that teaching approach is the main factor. A further study at the department is in progress to identify the mismatch in T&L of Statics, and later to rectify the situation.

With all the challenges identified and new pedagogies developed the authors strongly believe that T&L of Statics cannot remain 'static'. Transformation in T&L is no more an option but a necessity.

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