Implementing Technological and Pedagogical Advances in Very Large Group Teaching

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Abstract

The current paper describes some new technological and pedagogical advances that were implemented in the teaching of a course module *EG1104 Statics* to about 1400 students. The module was taught at the National University of Singapore as a first year common course for all engineering students as well as some cross-faculty students in the first semester. Besides the push by the government to develop "thinking" students and the general consensus by employers on the weakness of analytical, evaluating and planning skills shown by fresh graduates, some changes were carried out in this module in order to make a shift in the teaching paradigm from that of transferring information to that of processing information. In addition to the documentation of the specific techniques and details with regards to these advances, this paper will further provide an analysis of the feedback by students and staff, which shows the various merits in employing the techniques concerned and how they can be further refined for greater effectiveness.

1. Introduction

Over the last decade, many educators have come to realize the limitations of the traditional paradigm of education that implicitly views the primary goal as the effective transmission of knowledge content. In fact, as far back as 1916, Dewey, in his book entitled, *Democracy and Education* [1], presented a critique of the aforesaid paradigm. As an alternative, he offered what he called "progressive education". He consolidated his earlier findings in 1938 when he wrote another book, *Experience and Education* [2]. Many other authors have similarly highlighted the many shortcomings of the traditional way. One example is Gardner who, in his book, *The Unschooled Mind* [3], describes how otherwise competent college students do not "really understand" what they have learnt, even when showing a high degree of ability in solving standard textbook problems.

The Singapore Government, through the Ministry of Education, has collated many complaints from the employers about the quality of the graduates from its institutions of higher learning. It was reported in a major local newspaper how most graduates are seen to be lacking in creativity and initiative, are awkward, uncertain and vague, and unable to work independently, preferring to be spoon-fed and hand-held by their supervisors. There is a growing trend from the alumni and employers alike, who want graduates to have more than just a sound grounding in the fundamentals of the subject as detailed by Woods [4].

Other than the shortcomings derived from traditional teaching methods, another reason that new progressive techniques in education is growing popular is due to the rapid changes brought about by the recent advances in electronic networking and the relatively easy and inexpensive access to computers. With these changes, it has become imperative that educators take a fresh look at the traditional modes of teaching and assessment. The multitude of web sites, CD-ROMS, multi-media coursewares, videotapes etc, in addition to normal books, necessitates the shift of the focus of teaching from transferring information to that of processing information and to the inculcation of analytical abilities, application, critical and creative thinking and the capacity for independent learning. Technological advances, especially in the Information Technology realm, frees the educators to go into more progressive teaching techniques whilst at the same time not compromising the transferring of information. Computers can take care of the traditional part while educators should see this as an opportunity to implement the new learning paradigm, which focuses on the learning process, rather than the instruction paradigm, [5].

In the course *EG1104 Statics*, the educators set out to "test the water"; so to speak, with some new technological and pedagogical advances that embraces this new teaching paradigm. A paradigm that seeks to enhance the learning process and to cultivate "thinking" students for the challenges of the knowledge-based economy. This paper would describe the various advances implemented in this first-run and would also end with an analysis of their effectiveness through feedback obtained from tutors and students alike.

2. Class Profile

The class consists of about 1400 first year common engineering students. They were divided into three major lecture groups of about 450 each. Most of the students' population is made up of local youths who have gone through 16 years of formal education, which until recently, has focused on rote learning and transferring of information. Students are more often than not, spoon-fed and would not be used to independent thinking. These characteristics are important and should be noted while in the designing stage. The pedagogical approaches and the type of technological advances must be customized to suit the particular class so that students will not be shell-shocked. For example, in this class, in the implementation of one of the pedagogical advances, which was participatory workshop-lectures, the educators had to start off things slowly to encourage participation. This was because most of the students were not used to giving their opinions during class as opposed to what they have been through in secondary and junior colleges.

The assessment of the course consists of the following components: (1) three open-book quizzes (25%), (2) one exploratory laboratory experiment (5%), (3) web-based tutorials (10%) and (4) an open book examination (65%).

3. Participatory Workshop-Lectures

One problem of the conventional teaching method is in the presentation of the material. Frequently, lecturers tend to teach in the form of a monologue in front of a generally passive audience. This form of lecturing provides little incentive for students to attend classes. The fact that most of what they presented comes straight out of the textbooks and/or lecture notes compounds the problem. Only outstanding lecturers would be able to hold students' attention for

an entire period. There is a need to exploit students' interaction in class and to focus their attention on underlying concepts. Mazur [6] came up with a novel way of doing this by foregoing the method of presenting the material sequentially but rather, his lectures consist of a number of short presentations of the key points of the material, each followed by the so-called *ConceptTest.*

The educators for this module have adopted this technique and added other progressive teaching techniques where interaction amongst students and between lecturers and students are encouraged. In these participatory workshop-lectures, active learning can be an ultimate achievement, even with a large class size of about 450 students per session. Peer instructions via buzz groups are encouraged in lectures by posing concept quizzes (similar to Mazur's) and thought provoking puzzles at regular intervals during lectures. Printed lecture notes with critical information purposely "blanked" out also allow students to discover and learn during the workshop-lecture as they actively work through their notes, sometimes together with the lecturers.

Such techniques often require the contents of the lecture to be pruned judiciously. This is where the next two technologies can help in alleviating the worry of some lecturers of leaving out a lot of the syllabus just to implement these new techniques.

4. Live and Archived Web-Casting of Lectures

Through the collaboration with the Centre for Instructional Technology (a campus-wide centre to support NUS faculties and departments in online teaching and learning over the NUS intranet and the Internet), the Engineering Center for Information Technology and Applications (CITA), a faculty-level make-up, have adopted the technology of broadcasting lectures 'live'. As part of the drive to enhance the learning process of the *EG1104* module, the educators have embraced this new technology. Out of the three lecture sessions given per week, a 2-hr lecture on Mondays was also broadcasted over the Intranet 'live'.

Besides video and audio clips, presentation materials or lecture notes in the form of PowerPoint slides are also displayed on the web page and are synchronised with the video and audio parts. An example of how this would look like to a user online is shown below in Fig. 1.

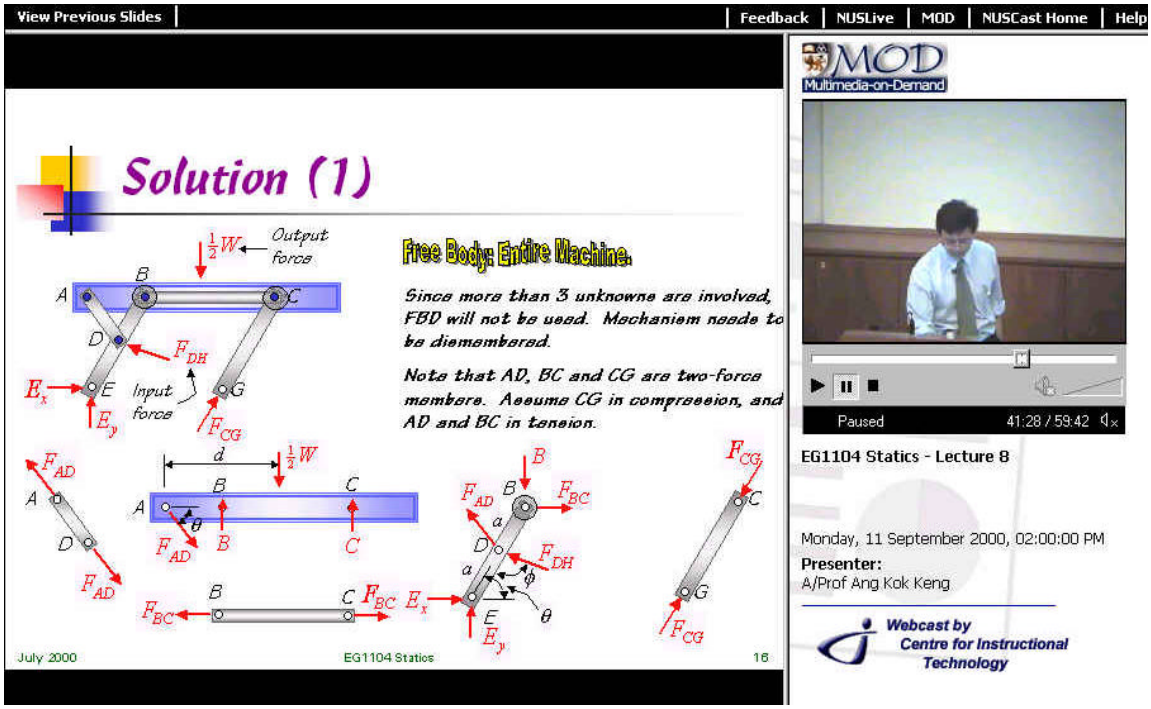


Fig. 1 – Web-cast Lecture

By web-casting lectures, students are accorded the convenience of being able to 'attend' lectures anywhere within the campus. Such lectures are also archived and deposited into the University's multimedia-on-demand server so that students can review portions of the lectures, if necessary, to reinforce their understanding of topics that were perhaps found difficult to grasp during the actual lecture. Besides this benefit, web-casting lectures in this way complements the participatory workshop-lectures and other progressive techniques of teaching where emphasis is more on understanding of concepts and thinking rather than rote learning from content-laden lectures. Most of these techniques require certain quarters to be given up, in this case, content of syllabus during lectures. With the implementation, lecturers need not worry about foregoing content in order to implement more progressive techniques.

For example, during the buzz groups' discussion, delays in the lectures may sometimes result especially when discussing difficult topics. Easier content which nevertheless needs to be included, may be dropped during lecture itself, with reminders for students to look it up on the archived website. The web-cast lectures can ensure the intended syllabus is covered.

5. Editable PowerPoint Slides

The lectures above were also complemented with the use of an innovative IT product that allows one to literally write electronic ink over an LCD monitor touch screen with a digitizing pen so that students can see the lecturer writing virtually over PowerPoint Slides. A schematic of the whole setup is shown in Fig. 2 below.

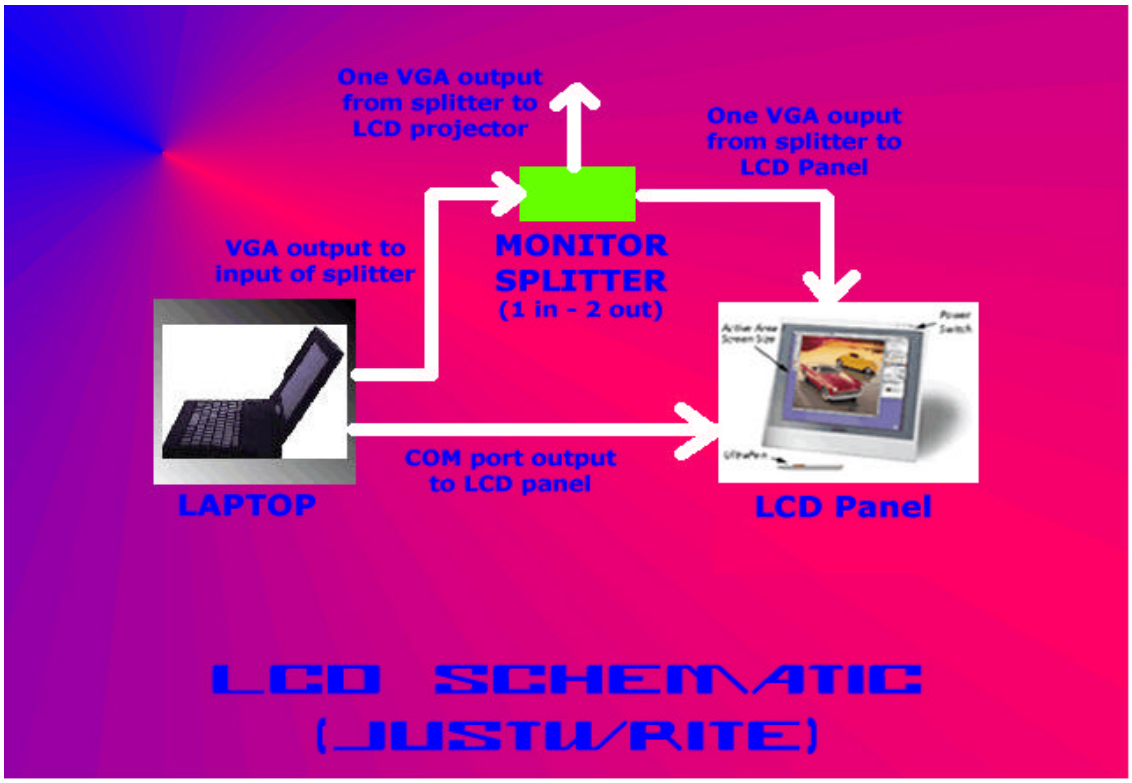


Fig. 2 – Editable PowerPoint Setup

The common grouse previously for PowerPoint files was the inability for easy editing or additions, which more than often are required while teaching. This ability is accorded easily by using the more traditional method of transparencies and marker. This has resulted in many lecturers still sticking to the latter method even though the former has many advantages. With the editability of the PowerPoint presentation plus the dynamism of the PowerPoint slides, presentation of the lectures can be significantly improved. Also, in view of the notes being in PowerPoint format, the above web-casting technology may be readily implemented. Thus the LCD writing technology helps to bring greater versatility to the PowerPoint presentation.

The figures below show the LCD technology at work. (Fig. 3 shows the digital ink over a PowerPoint slide as seen by the students while Fig. 4 shows the setup at the front of the Lecture Theater).

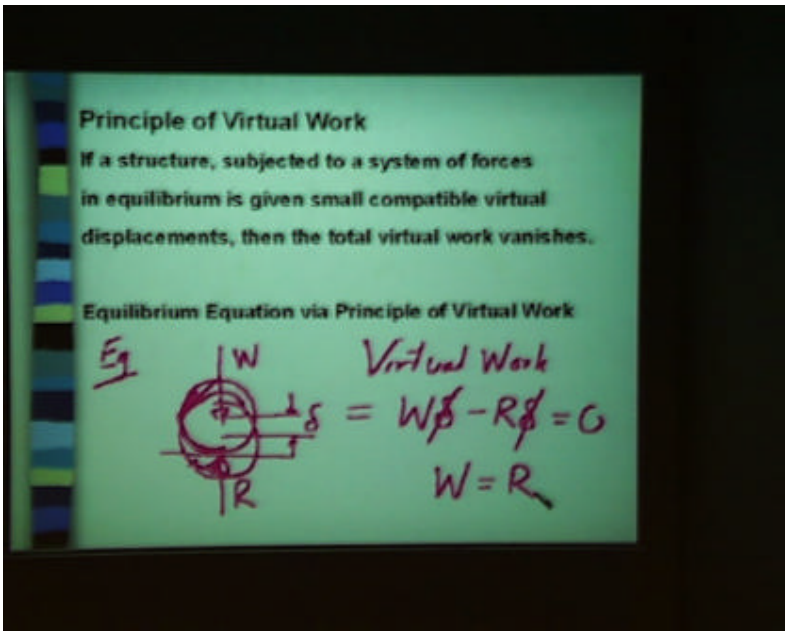


Fig. 3 – Writing on PowerPoint Slide

Fig. 4 – LCD setup in the lecture theater

6. Advanced Web-based Tutorial System

Many web-based systems have been developed and implemented at various institutions of learning to aid in teaching, tutoring and assessment of suitable modules. Often, the latter aspects have been limited to multiple-choice questions, which have few or no diagnostic and assessment capabilities. The web-based tutorial system deployed for this particular module features a wider

variety of question-types for deployment, a more advanced and intelligent diagnostic system and comprehensive monitoring and assessment capabilities.

The ability of the system to deploy a variety of different types of question was the key in adopting this system. At the first year engineering level, tutorial questions have always consisted of single-answer questions, not multiple-choice ones, normally churned out by web-based systems. Initially, the system adopted was only able to handle single-answer questions, but through the use of new JAVA applets developed, the system was improved to include multiple-answer type of questions. An example of a typical single-answer type of question, a multiple-answer type of question and a diagnostic pop-up window are shown in Fig. 5 below.

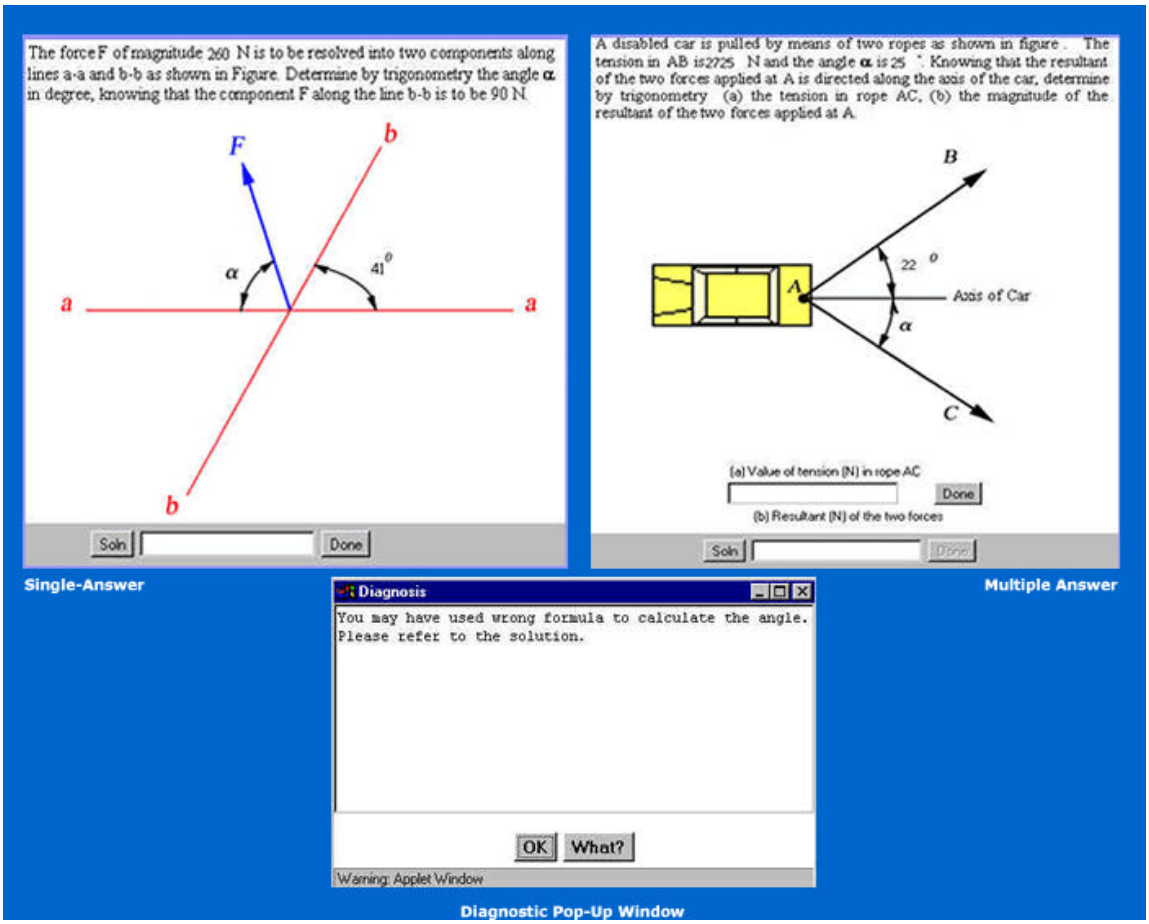


Fig. 5 – Advanced Web-based Tutorial System

A student, after working out a certain problem, would key in the numerical answer in the answer field. For the multiple-answer questions, students would have to key in the correct answers in a sequential fashion before they can move on to the next part. Depending on the accuracy of the answers given, different diagnostic pop-up windows would appear. This is where the strong diagnostic capabilities of the system come through. The system can be 'trained' to diagnose common mistakes students make during problem solving. For example, if a common mistake in solving a particular problem was to take ***g*** (gravitational constant) to be 10 m/s^2 instead of the

correct value of 9.81m/s^2, the system would display to the student that a mistake has been made possibly due to the use of an inaccurate value of ***g***. Whilst other systems may just give a right/wrong feedback to the user, this system is able to give a much better feedback to the user, and hence, a better diagnostic capability. To discourage copying, the parameters used in the tutorial questions are randomized and are unique for each student. Students are however encouraged to collaborate and solve the problems together if they so wish since collaborative learning is considered as desirable as individual learning.

The diagnostic capability is important in the overall scheme of shifting to the learning paradigm scenario. With the efficiency of a web-based tutorial system nearing that of a real-tutor, in helping students cope with problem-solving skills, progressive techniques in tutoring can be employed to inculcate more thinking and creative skills which are somewhat lacking nowadays. This is another example similar to the lecture web-casting, where technology can be used to take over some of the traditional roles in the teaching process so that educators can devote resources, time or otherwise, on the more progressive techniques such as the participatory workshop-lectures or the inquiry-based tutorials that would be discussed in the next section.

Another aspect of this system that helps the progressive scenario is its comprehensive monitoring and assessment capabilities. From its monitoring window, which is part of the system's program, educators can monitor the students' performance in the tutorials at a glance so that students who are lagging behind may be identified at an early stage despite the huge class size. It would also allow them to see which questions students are having trouble with by viewing the progress display. Such information would enable the lecturer to teach more effectively since students' errors in attempting questions are known before hand. A snapshot of what this monitoring window entails is shown in Fig. 6 below.

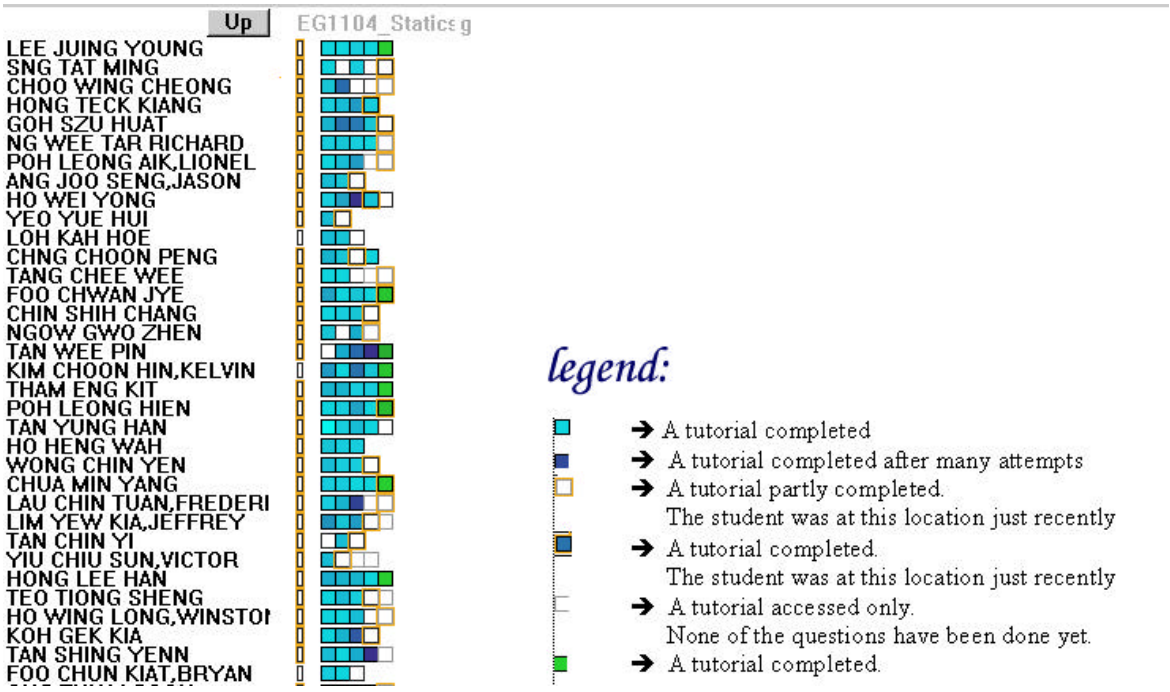


Fig. 6 – Monitoring Window showing student's progress in web tutorials

From the same system, assessment of the marks acquired can be easily tabulated and exported appropriately to a database for easy retrieval. The ease at which monitoring and assessment can be done frees educators to design and implement progressive teaching techniques in a more involved manner.

7. Inquiry-Based Tutorials

The shift of focus from instruction to learning needs to be reflected also in the tutorial questions that are developed. The design of the questions should be such that they test, and thereby actively require of students, the higher cognitive process. This higher form of learning entails a deeper understanding of the subject matter (including critical understanding) and thoughtfulness, as indicated in thoughtful application in novel situations. These questions also test originality, imagination or creativity. These forms of higher learning are in contrast to the rudimentary forms of learning such as recall and familiarity of subject matter, relatively mechanical reasoning, as reflected in tasks that require mechanical application and routinizable procedures to standard classroom problems.

It is with the goal of encouraging the higher forms of learning that the educators have come up with the inquiry-based tutorials, which complements the standard tutorials that were deployed in the web-based system. These tutorials are conducted during school-time while the web-based ones can be done anytime, anywhere using any device.

These inquiry-based tutorials are essentially created to provide opportunities for students to develop their inquiry skill that is so essential for life-long learning. The questions in these tutorials are designed to provoke questioning from the students due to their vagueness, open-ended nature, real world like and novel problems. In these tutorials, the students are encouraged to 'spar' with their tutors and among themselves. Two examples of such questions are shown below in Fig. 7a and 7b.

In the first example, the students have to understand cable analysis, which was taught in class, and the contents of a given technical paper. The bodies of knowledge in both the sources have to be synergised in order to develop a method for determining the optimal profiles of cables. This is a research exercise, requiring them to construct new knowledge.

In the second example, the student is required to apply their understanding on the concepts of free body diagram and equilibrium to a non-standard problem complicated by a non-uniform pressure at the base of the Pisa tower [7].

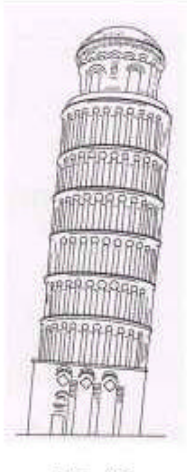
1. Rozvany and Wang [1,2] have developed a simple procedure in determining the optimal shape of fully stressed arches (i.e. the axial force at any cross-section of the arch divided by the cross-sectional area is equal to the maximum permissible stress value s_o) the subjected to vertical loads. When inverted, these arches become fully stressed cables of varying cross-section. However, for practical purposes, the cross-section should be kept constant. Your task is to propose a method for obtaining the shape of a constant cross-section cable whose volume (or weight) is to be a minimum. The cable is subjected to any vertical load system. The selfweight of the cable may be assumed to be negligibly small. In the entire cable, the stress (axial force divided by area) cannot exceed the maximum permissible stress value s_o.

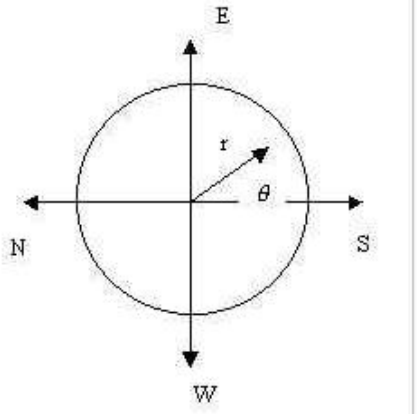
(a)

2. The Leaning Tower of Pisa, Italy, built in 1350, is 58.2 *m* tall and has a circular base of diameter 19.6 *m*. For the past several centuries, its longitudinal axis has been inclined by 5.6° toward the south from the vertical (see Fig. 2a). The weight of the tower is 144 *MN*. The diameter of its cross-section changes slightly from bottom to top, and accordingly its centre of gravity is approximately 27.1 *m* above the base. The pressure that the sandy, claylike soil exerts on the rigid, circular base slab of the tower may reasonably be approximated with the relation

$$p = C_1 + C_2 r^{0.625} \cos q \qquad N/m^2$$

where r and q are polar coordinates (with q measured due south as in Fig 7b) and C_1, C_2 are constants to be determined. Find the maximum and the minimum pressures exerted on the base of the tower by the soil and give their locations.





(b)

Fig. 7 – Example of Inquiry-Based questions

8. Analysis of Feedback

Feedback was culled from both students and tutors. For the former, they were mostly gathered from an online survey which students were required to complete in order to finish their tutorials. Informal feedback to tutors makes up the rest. As for the tutors, an end of term meeting was held to gather their feedback on the course, tutorial problems, quizzes and exam questions.

Fig. 8 below shows an overview of the questions that were asked and the responses gathered from students in the online survey.

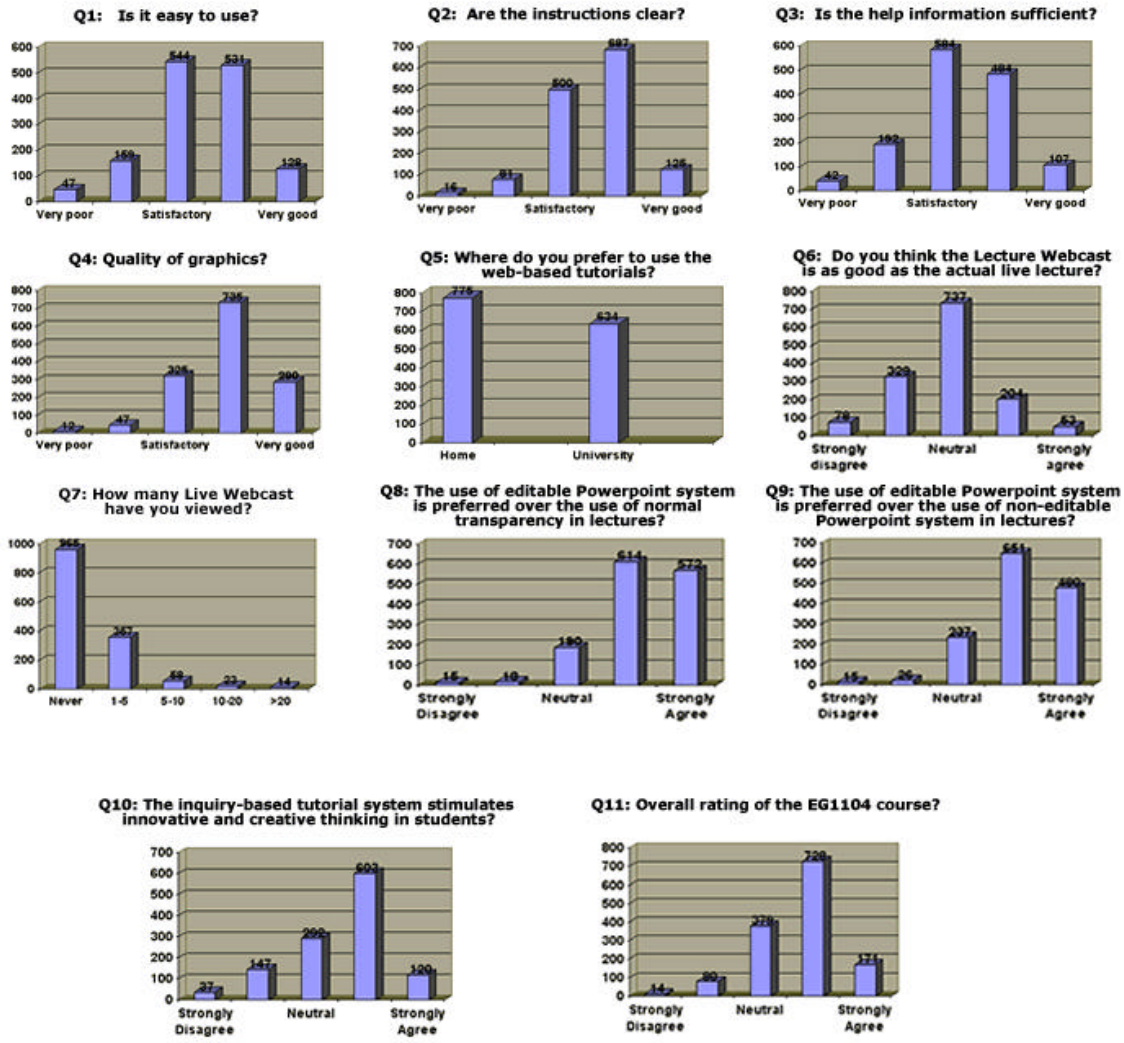


Fig. 8 – Survey Results

Questions 1 to 5 deal with the web-based tutorials, questions 6 and 7 focus on the web-casting, questions 8 and 9 on the editable PowerPoint system, question 10 on the inquiry-based tutorials,

while question 11 asks for a general overview of the whole course vis-à-vis these new advances. Comments were also received from the feedback.

Looking at the web-based tutorials' responses, it can be seen that a majority of the 1409 students (from 84% to 93%) sees the aesthetics and the user-friendliness of the system as key advantages of the system. From question 5, the survey shows that slightly more students (141) prefer to use the system at home than at school. The latter aspect would explain most of the grouses that was received in the comments aspect of the survey towards the web-based tutorial system. Due to the new nature of this system, small teething problems still exist when students logged in from home. With the majority wanting to log in from home, where various system configurations exist, problems do occur. Other than logging in from home problems, students see the web-based system as something useful and exciting as opposed to the normal tutorials.

> One student remarked that "…*It'll be good for all students if most engineering modules take up the teaching methods employed in Statics, especially the i-tutorials (the web-based tutorials) because students who have been doing it closely will know how much they understand*…"
>
> In the same vein, another student commented, "…*The lecturers have done a very good job, and I think that the idea of i-tutorial is very good. It makes students keep pace with what is being taught, and should be incorporated to all subjects.*…"
>
> Reflecting on the home logging in problems, a student quoted, "…*Except for problems with logging in from home, the iTutorial has fared very well in its debut*…"

As for the effectiveness of the web-cast lecture as a substitute to physically attending a lecture, results on question 6 show that about 20% found it to be effective, while the majority (about 50%) was neutral to the idea. This can be attributed to the fact that a majority did not view a web-cast lecture, be it live or archived, which can be concluded from question 7. Although this points to a need for a more concentrated effort on the part of lecturers and tutors to publicise the existence of these web-casts, this does not preclude the fact that for those who watched, more than 55% appreciate its effectiveness. A resounding 80 to 85 % of students voiced their approval of the use of the editable PowerPoint system over normal transparencies and/or non-editable PowerPoint systems.

As for the inquiry-based tutorials, about 51% of students felt that it stimulates innovative and creative thinking in students. There was some feedback though, about the degree of difficulty of some of the questions.

> One student was quoted as saying, "…*The inquiry-based tutorials although are challenging, they are often too difficult to understand*…"

A careful approach has to be adopted in creating these questions so that they would not turn out too complex and would encourage inquiry. The last question, which asks for the students' assessment on the whole Statics course returns a 65% approval rating, which is a positive

testimony to the advantages and effectiveness of the various pedagogical and technological advances introduced.

> One student's comment, which typically reflects the sentiment on the course effectiveness, reads: "…*This is an excellent module. The lecturers were great, the PowerPoint presentations and notes were clear, and the I-tutorials were a worthwhile learning exercise. This module is far better taught than any of my other modules. Thank you*…"

With the above, it was clear that students appreciate the advances implemented in the course albeit, with some improvements and changes.

9. Recommendations and Future Directions

For the advanced web-based tutorials, the robustness of the system needs to be improved so that students logging in from home would not face the niggling problems they faced now. The almost fault-free logging in situation from campus should be duplicated for the home login. Secondly, a formula-input question template is to be developed to allow students to key in mathematical expressions as answers other than the numerical ones that students are able to do now.

As for the web-casting, the development of a reliable system that changes the bit-rate and the quality of the web-cast according to the Internet connection should be looked into and should be a reality with the new version of the windows media software. This automatic detection would allow students to also view the web-cast from home, thereby furthering the reality of anytime, anywhere learning. The inculcation of the editable PowerPoint System into every Lecture Theater in the Faculty of Engineering is in the pipeline and should make the setting up easier. Lastly, the inquiry-based tutorials should be developed further so as to include more questions and should not stray into creating questions that are too complex but rather inquiring ones.

10. Conclusions

The need for adopting new pedagogical and technology advances in teaching and learning has been highlighted. The various advances that were adopted in a first-year engineering course in NUS have been detailed with key features explained. Analysis of the feedback received from students and tutors have been done and a positive response has been culled from students and tutors alike. With further improvements and recommendations, some of which are highlighted, the teaching and learning experience can be enhanced further.

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