Using Visualization Tool to Help Engineering Students Learning Dynamics

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***Abstract**: Dynamics is an essential core engineering subject. It includes high level mathematical and theoretical contents, and basic concepts which are abstract in nature. Hence, Dynamics is considered as one of the hardest subjects in the engineering discipline. To assist our students in learning this subject, we have conducted a Teaching & Learning project to study ways and methods to effectively teach Dynamics based on visualization techniques. The research project adopts the five basic steps of Action Learning Cycle. It is found that visualization technique is a powerful tool for students learning Dynamics and helps to break the barrier of students who perceived Dynamics as a hard subject.*

Introduction

In recent years, more and more attentions have been directed to engineering education (Felder, 1998, 2000, 2006; Felder et al., 2000; Olds et al., 2005; Reeves et al., 1999). The issues in teaching Dynamics subjects have been studied and reported by many teachers and researchers (Cornwell, 1996; Kummar and Plimmer, 1997). Dynamics is an essential core engineering subject and it is considered as one of the hardest subjects in the engineering discipline. The failure rate of students studying this unit is usually higher than those of other engineering units. It has been found that the Dynamics unit includes a broad range of theoretical contents and abstract concepts; and requires strong mathematical skills. Many students acknowledged that, in the Dynamics unit, it is very hard to understand and comprehend the abstract concepts through traditional teaching methods with normal tutorials and assignments. Hence, the conclusion can be drawn that the difficulty lies in understanding of the abstract concepts which is the main barrier for students learning Dynamics.

With fund provided by the School/Faculty Teaching & Learning Development Grant, we conducted an investigation on the usage of practical tools and exploration of innovative teaching methods for teaching dynamics subjects in QUT. A major part of this project was to investigate the application of visualization technique to help students learning the unit with the fundamental theory displayed in the physical space. The objectives of this research include: 1) to develop and supplement visualization materials in teaching; 2) to collect essential data for understanding the issues faced in teaching Dynamics ; 3) to study possible innovative teaching techniques to help students learning Dynamics; and 4) to investigate the effectiveness of visualization technique in teaching Dynamics. To fulfil these objectives, we conducted the research based on the following five basic steps of Action Learning Cycle (Boman, 2008) including: Identifying problem, Planning action, Implementing, Evaluating, and Reporting.

Problem Identification

Dynamics is a fundamental engineering unit and the students need to use the basic dynamics knowledge in their following engineering units including engineering designs, analyses and

applications. Hence, Dynamics is a core unit for all engineering students. However, many engineering students perceive it as one of the hardest units in the engineering course, and they performed worse in the Dynamics unit than in other engineering units. This rises to the following questions: "is there something wrong in teaching this unit? What is the major obstruction for students learning this unit?"

To identify the issues, we studied the current unit outline, teaching contents, slides, assignments, and discussed with previous students. We have found that the Dynamics unit has the following characteristics:

- It includes a wide range of theoretical contents, abstract concepts, and it requires fundamental mathematical knowledge, e.g., coordinate systems, vector, velocity, acceleration, force, vibration, etc.;
- We still use the traditional teaching methods, which are based on lecture, understand of formulae and apply them to solving problems;
- Many tutorial problems are too abstract and do not link with the real world situations; and
- Assignments are designed to train students' problem solving ability and they are not sufficient to help students understanding the basic concepts in this unit.

From the students' feedback, we have learned that many students responded that in the Dynamics unit, it was very hard to understand and grasp these abstract concepts only through traditional teaching methods and current tutorials/assignments. It can be concluded that the difficulty in understanding abstract concepts is the main barrier for student learning the Dynamics unit. Therefore, there is a need to answer the following crucial question: "how to effectively teach Dynamics with a amount of theoretical contents and abstract concepts". Hence, the following study aims:

- to collect essential data to understand the issues in teaching and learning Dynamics, which requires to cover both theoretical contents and abstract concepts; and
- to investigate the effectiveness of using visualization technique in teaching Dynamics.

Methodology/Strategies

To fulfil the above mentioned objectives, we adopted the following Action Learning Cycle (as shown in Fig. 1) (Boman, 2008; Pedler, 1997). As discussed above, the difficulty in understanding abstract concepts is the main barrier for students learning Dynamics. If the abstract concepts can be visualized, it can provide a visual observation of a situation and will be definitely helpful for students' learning and understanding. As the core part in the revolution of the teaching techniques for the Dynamics unit, we focus on studying the application of the visualization technique in teaching Dynamics.

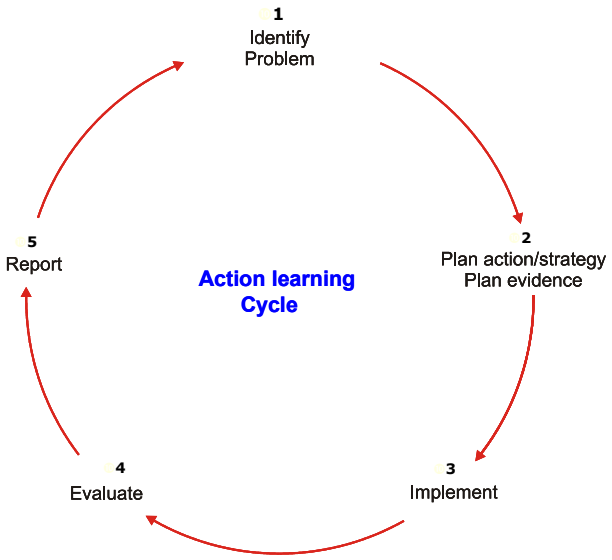

Fig. 1 Action learning cycle

The visualization technique is a modern technique for creating images, diagrams, or animations to communicate message and information via imagery manner. Visualization through visual imagery has been an effective way to communicate both abstract and concrete ideas (McGrath and Brown, 2005; Zimmermann and Cunningham, 1991).

There are several powerful visualization software packages available in QUT computer laboratories. To use the visualization technique in this unit, we have conducted the following actions/ strategies in Semester I of 2009:

1) Extending the application of the Interactive physics® (IP) software, which is a powerful tool to create and visualize many physical phenomena: Students are required to learn and practice IP in the computer laboratories to visualize basic concepts learned in the class.
2) Re-developing teaching slides by incorporating visualizations images to display the theories and concepts: Teaching slides are thoroughly re-developed to add visualization contents including pictures, movies, drawings, tables, and so on.
3) Re-designing assignments to help students' comprehension of the contents taught in the unit: Based on the teaching contents, we design some new assignment problems and students are requested o solve these problems using both theoretical methods and the visualization techniques. Through the comparisons, students will understand and grasp the knowledge involved in these problems.

The following is the timeline for our study:

- At the beginning of 2009: to briefly review and summarize the outcomes obtained in 2008: this aimed to summarize and evaluate the initial outcomes in order to find out the successful or unsuccessful points and develop improvement strategies accordingly;
- Semester I of 2009: to fully apply visualization technique to the Dynamics unit; and
- End of semester I of 2009: to evaluate and develop further improvement strategies for the next Action Learning cycle.

We have collected and evaluated data through the following processes:

a) to analyze LEX scores and written comments: LEX (Learning Experience Survey) is a formal on-line survey tool in QUT to collect students' evaluations of the teaching and unit;
b) to analyse the final examination grades and compare them with previous results;
c) to collect evaluation data from peer feedback; and
d) to collect data from the students' feedback in a "one-minute" survey in the class. In the "one-minute" survey, the students were asked four questions: *1) What did you learn from this class? 2) What were you still confusing? 3) Did the visualization materials help you understand the concepts? 4) Other comments.*

Evaluation and analysis of the outcomes

One-minute survey

The one-minute survey was conducted in week 9 (1 May 2009), and we received 41 feedbacks. For the Open Answer Question 4), "Other comments", the students highlighted that Dynamics is a hard unit.

From the answers for Q1, we drew a conclusion that most students (79%) have learned the fundamental of rigid body and its motions. This shows that the students have understood and grasped the major concepts in this lesson.

From the answers for Q2, almost half of the students (42%) have understood all the teaching contents delivered in this class without any confusion. Considering the survey results for Q1 and Q3, we have found that the lecture and presentation materials in this class were successfully delivered. The visualization materials used were helpful for students' understanding of the abstract concepts and formulae discussed in the class. However, five students (13%) were still confused with the '*Triangle Linkage example',* which was a model of a real machine and was used for the first time in the unit . Although we had prepared several images and a movie of this linkage mechanism, from students' feedback, we realized that we may have discussed this example too fast and students were not given enough time to think and follow this example and the visualization materials. In addition, it was realised that the explanation of the visualization materials was insufficient.

From the answers for Q3, it is clear that most of the students (87.8%) agreed that the visualization materials used in this semester were very helpful for their learning the theoretical contents and abstract concepts in this unit. However, we also noted that two students responded that the visualization materials were *NOT* helpful and one student responded that the visualization materials were only *SLIGHLY* helpful. One of these students mentioned that, for some visualization materials (movies, pictures, and computer models, etc.), we only provided very limited introduction and explanation about the background of them. These explanations seemed insufficient for some students to fully understand the basic concepts via visualization. Without good explanations, the visualization materials will have very limited benefit and may even confuse some students. We have learned a lesson from these feedbacks and concluded that for every visualization file (movie, picture or the animation slides), a detailed description and explanation should be provided as well, especially to indicate the concepts/ principles behind this visualization content.

LEX Survey

LEX is the official on-line survey system in QUT and it has become an important tool for students to evaluate the teaching and delivery of the unit. To evaluate the outcome of using visualization tool in Semester I of 2009, the latest LEX scores of 2009 were compared with those of 2008.

The teaching score for the teaching team in 2009 has shown a significant improvement of about 8%. One major reason for this improvement could be attributed to the use of new visualization materials.

Figure 2 shows the comparison of satisfaction rates for 'lecture/ presentation' in LEX. It clearly shows that more students were satisfied with the new delivery mode in 2009 than in 2008. A major change in teaching Dynamics in 2009 is adoption of visualization materials and this has definitely contributed to the improvement of the overall teaching and presentation quality.

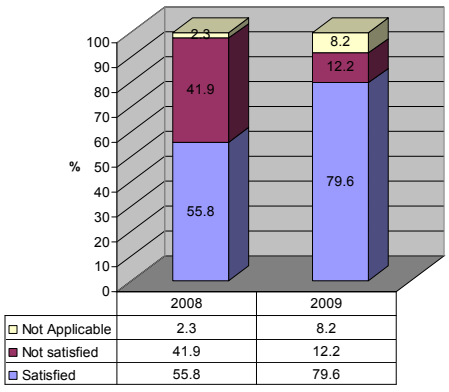

Figure 2: LEX for Lecture/Presentation

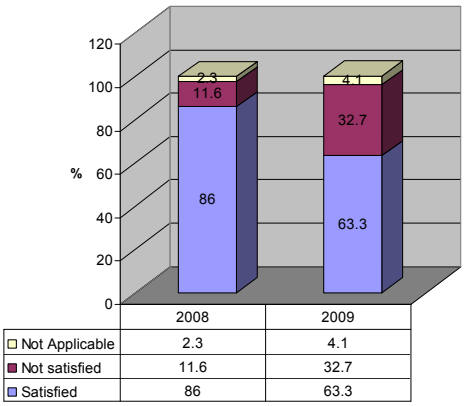

Figure 3: LEX for Tutorials

Satisfaction rates for 'Practical/Lab/Studio' and 'Unit materials' were improved as well.

Figure 3 plots the comparison of the satisfaction rates for 'Tutorials'. In 2009, the satisfaction rate for tutorials showed a significant decrease. To unveil the reason for this unsatisfactory result, we personally discussed with the tutors and some students. We realized that some tutors were not familiar with the visualization materials which were used for the first time in 2009. The tutors were not ready to provide comprehensive explanations of the visualization materials and lacked experience to link the tutorial contents with the visualization materials. This result indicates to us that to properly train tutors on the usage of visualization materials is a crucial factor to ensure the effectiveness of the visualization materials in teaching.

In summary, we have learned a lot from the comparison of the LEX scores. The visualization technique is considered as a powerful tool in helping students' learning the theoretical contents and abstract concepts in Dynamics. However, some further improvement is needed.

Peer-review and observation

We invited one of our colleagues, Dr. Jack who is the Faculty Learning and Teaching Consultant and Ms Isherwood who is a lecturer in the Health Faculty to visit and observe one of our classes.

In Dr. Jack's feedback, she highly admired the teaching techniques used: *"The use of numerous, excellent teaching aids and illustrations complemented his teaching as did the provision of summaries. This lecture was an excellent example of sound presentation of theory as well as application of theory."*

In Ms Isherwood's feedback, she highlighted the visualization techniques used in the class. She firmly believed that the visualization technique is really a power tool for teaching engineering theories: *"Power points- wow, I want to learn how to do those moving ones, they were great and were a thoughtful mixture. You had text slides that supported what you spoke about. The moving diagrams showed visually exactly what you were describing…"*

In summary, our peers highlighted the presentation and visualization techniques used in the class to assist students learning of the unit. They believed it is a sound way for teaching theory as well as application of theory.

Final exam grades

Table 1 lists the comparisons of distributions of grades and average marks for Dynamics in 2008 and 2009. It should be mentioned here that the same teaching team was used in 2008 and 2009. The major difference in teaching was that more visualization materials were used in 2009 than in 2008. From Table 1, we can clearly see that in 2009, the average mark has increased (3%). In addition, more students get 6– 7 grades (7:High Distinction, 85%-100%; 6: Distinction, 75%-84%) in 2009. It has proven that students perform better in exams in 2009, because the students had a better understanding of the teaching contents in this unit. We believe that this improvement is likely due to the adoption of new visualization materials in 2009. However, we are slightly disappointed that the failure rate is almost the same in 2008 and 2009. It can be concluded that the new visualization materials have improved students understanding of the unit as indicated by the number of higher achievers (grade 6~7) than the under-achievers (grade 1~3). In our next iteration of the T&L research, we will try to identify this issue and to find ways to reduce the failure rate. Again, it is a challenge on how to help the under-performed students in the Dynamics unit.

Table 1: Comparisons of final results for ENB211

Item	2008	2009	Change rate
Student numbers	131	148	
Rate for grade 6~7	14.5%	21.6%	7%↑
Average mark	55%	58%	3%↑

Conclusion and recommendations

From a number of channels, we have known Dynamics is considered as one of the hardest units in engineering discipline. The main issue and barrier in learning Dynamics are that Dynamics includes large amount of theoretical contents and abstract concepts. Hence, there is a huge challenge on how to effectively teach Dynamics. Through our studies, we have drawn the following conclusions:

(1) The visualization technique can definitely help students in learning and comprehending the abstract theories and concepts of Dynamics.

(2) The visualization materials without sufficient explanations can impede some students to fully understand the basic concepts behind the visualization materials. Hence, by only developing and providing visualization materials without sufficient explanation is not enough. Proper and sufficient explanations for all visualization contents should be also prepared and provided.

(3) Tutors play a very important role in boosting and ensuring the effectiveness of using visualization materials. If tutors are not familiar with the visualization materials, they will not be able to provide a good explanation of the visualization materials. The lack of experience to link the tutorial

contents to the visualization materials can also reduce the effectiveness of visualization. The results remind us that to properly train tutors for the usage of visualization materials is also a crucial factor to ensure the success of using visualization materials in teaching Dynamics.

As a closed cycle, some important activities are recommended for the next iteration of the action learning cycle:

a) To properly train tutors in using visualization materials;

b) To develop detailed description and explanation for visualization files (movie, picture or the animation slides);

c) To develop and adopt more visualization materials not only for teaching in classes, but also for tutorials and computer laboratories; and

d) To collect and evaluate data for further improvement.

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