Visualization - A Powerful Tool for Effective Teaching of Dynamics

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Abstract *— Dynamics is an essential core engineering subject and it is considered as one of the hardest subjects in the engineering discipline. Many students acknowledged that Dynamics is very hard to understand and comprehend the abstract concepts through traditional teaching methods with normal tutorials and assignments. In this study, we conducted an investigation on the application of visualization technique to help students learning the unit with the fundamental theory displayed in the physical space. The research was conducted based on the following five basic steps of Action Learning Cycle including: Identifying problem, Planning action, Implementing, Evaluating, and Reporting. Through our studies, we have concluded that visualization technique can definitely help students in learning and comprehending the abstract theories and concepts of Dynamics.*

Index Terms *— Action Learning Cycle, Dynamics subject, Engineering education, Visualization teaching technique,*

INTRODUCTION

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 subject is usually higher than those of other engineering subjects. It has been found that the Dynamics subject includes a broad range of theoretical contents and abstract concepts; and requires strong mathematical skills. Many students acknowledged that 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.

In this paper, we conducted an investigation on 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 collecting essential data to understand the fundamental issues faced in learning Dynamics, and to investigate the effectiveness of visualization technique in teaching Dynamics. To fulfil these objectives, we conducted the research based on five basic steps of Action Learning Cycle including: Identifying problem, Planning action, Implementing, Evaluating, and Reporting. This study is a closed cycle which started from 2008 and 2009. Through our studies in 2008 and 2009, 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 on the usage of visualization materials is also a crucial factor to ensure the success of using visualization materials in teaching Dynamics.

In the begining of 2010, more data were collected and investigated. Some important ongoing activities to improve the application of visualization tool in teaching of dynamics as the next iteration of the action learning cycle: including to properly train tutors in using visualization materials; to develop detailed description and explanation for visualization files (movie, picture or the animation slides); to develop and adopt more visualization materials not only for teaching in classes, but also for tutorials and computer laboratories; and to collect and evaluate data for further improvement.

PROBLEM IDENTIFICATION

Dynamics is a fundamental engineering unit and students need to use the basic dynamics knowledge in advanced engineering units including engineering designs, analyses and applications. Hence, Dynamics is a core subject for all engineering students. However, many engineering students perceive it as one of the hardest units in engineering course, and they performed worse in the Dynamics subject than in other engineering subjects. To identify the issues, in 2009, we studied the unit outline, teaching contents, PowerPoint slides, assignments, and interviewed previous students. We have found that the Dynamics subject has the following characteristics:

- Dynamics includes a wide range of theoretical contents, abstract concepts, and it requires basic mathematical knowledge, e.g., coordinate systems, vector, velocity, acceleration, force, vibration, etc.;
- Traditional teaching methods are still being used, 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 subject, 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 subject. Therefore, there is a need to answer the following crucial question: "how to effectively teach Dynamics with sufficient amount of theoretical contents and abstract concepts". Hence, the following study aims: to collect essential data to understand the issues faced in the teaching and learning of 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 fulfill the above mentioned objectives, we adopted the Action Learning Cycle [1]. 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 teaching techniques for Dynamics subject, we focus on studying the application of the visualization technique in teaching Dynamics.

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 [2]-[5]. 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 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 running IP in the computer laboratories to visualize the basic concepts learned in the class.
(2) Re-developing teaching power point 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 reinforce students' comprehension of the contents taught in the unit: Based on the teaching contents, we designed some new assignment problems and students are requested o solve these problems using both theoretical methods and the visualization techniques. Through comparisons, students will understand and grasp the knowledge involved in these problems.

We have collected and evaluated data through the following processes:

- 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;
- to analyze LEX (Learning Experience Survey) results: LEX is a formal on-line survey tool in QUT to collect students' evaluations on the teaching and content of the unit. In 2010, we have obtained and analized increaded data from LEX;
- to analyse the final examination grades and compare them with previous results.

EVALUATION AND ANALYSIS

One-minute survey

The one-minute survey was conducted, 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 Q2, 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.

Students were also asked to answer the question: Q3: "Did the visualization materials help you understand the concepts?". The feedback results for this question are summarized in Table 1.

From Table 1, it can be clearly seen that most of students (87.8%) believed that the visualization materials introduced and used in this semester were very helpful for their learning of theoretical contents and abstract concepts in Dynamics. Hence, the conclusion can be drawn that visualization technique is a powerful tool to reinforce effective learning of hard engineering units with many theoretical contents and abstract concepts. Some written comments from students also supported this conclusion:

- ✓ *'The visualization materials added practical touch to learning.'*
- ✓ *'Yes, I did use it to aid my studies; improve understanding.'*
- ✓ *'They are very helpful. Please add more.'*
- ✓ *'The visualization went well with what lecturer wanted to emphasize.'*

Student Answer	Number	Percentage
Yes, they are very helpful	36	87.8%
Yes, but they are only SLIGHLY helpful	1	2.4%
Not Helpful at all	2	4.8%
NIL—no answer for this question	2	7.4%
Total	41	100%

TABLE 1ONE-MINUTE SURVEY SUMMARIZATION

However, in Table 1, it is shown that two students answered that the visualization materials were NOT helpful and one student answered that the visualization materials were only SLIGHLY helpful:

- × '*Not really helpful—sometime they confused me more, maybe they could have more explanation as to what is happening.*"

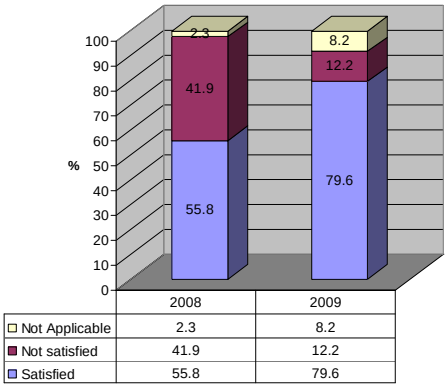
This is an important negative feedback which indicates that some students (about 5%) did not satisfy with the visualization materials used in this unit. As that student mentioned, for some visualization materials (movies, pictures, and computer models, etc.), onlylimited introductions and explanations were provided about the background of them. These explanations were no sufficient for some students to obtain ful understanding of the basic concepts behind the visualization. Without good explanations, the visualization material will have very limited benefit and can even confuse some students. We have learned a lesson from these feedbacks and obtained a further improvement strategy: 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 from using visualization tool in 2009, the latest LEX scores of 2009 were compared with those of 2008.

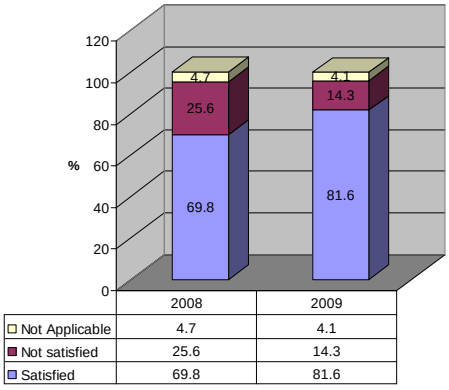
The teaching score from the teaching team in 2009 has shown a significant improvement. One major reason for this improvement could be attributed to the use of new visualization materials.

Figure 1 plots the comparison of the satisfaction rate for 'lecture/ presentation'. It clearly shows that more students are satisfied with the visualisation presentation in 2009. The major change for teaching in 2009 is the adoption of visualization materials which have definitely improved the overall teaching and presentation quality.



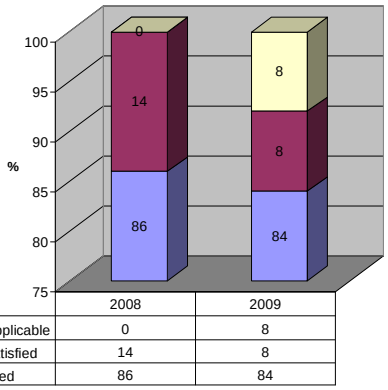
	2008	2009
Not Applicable	2.3	8.2
Not satisfied	41.9	12.2
Satisfied	55.8	79.6

FIGURE 1
LEX FOR LECTURE/PRESENTATION



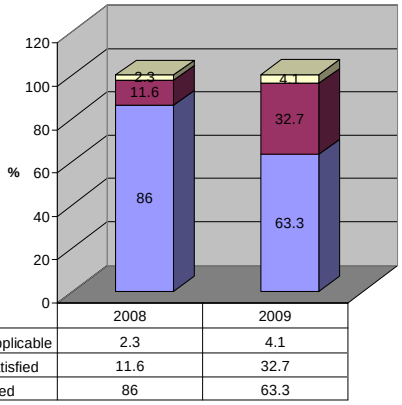
	2008	2009
Not Applicable	4.7	4.1
Not satisfied	25.6	14.3
Satisfied	69.8	81.6

FIGURE 2
LEX FOR PRACTICAL/LAB/STUDIO



	2008	2009
Not Applicable	0	8
Not satisfied	14	8
Satisfied	86	84

FIGURE 3
LEX FOR UNIT MATERIALS



	2008	2009
Not Applicable	2.3	4.1
Not satisfied	11.6	32.7
Satisfied	86	63.3

FIGURE 4
LEX FOR TUTORIALS

New computer lab assignments have been designed and adopted in order to encourage students to use Interactive Physics visualization software in the laboratories and assignments. Figure 2 plots the comparison of the satisfaction rate for 'Practical/Lab/Studio' in LEX. The satisfaction rate for new labs in 2009 increased a big margine. It has proven that most students like the new computer labs and assignments which are based on the visualization tool.

Figure 3 plots the comparison of the satisfaction rate for 'Unit materials'. It should be mentioned here that the only major difference in the unit materials is that more visualization materials are used in 2009 compared to that in 2008. Hence, from the change of Satisfaction rate for Unit materials, we can conclude that the students' evaluation has been influenced by the new visualization materials. From Figure 3, it is shown that, in 2009, fewer students ticked "not satisfied" for the unit materials which have been improved and enriched by the introduction of visualization materials. However, the satisfaction rate seems not improved because there were more students select "Not-applicable". This result is very similar to the results obtained in the one-minute survey. Although most of students believed that visualization materials are very helpful, some students thought the benefit from the current visualization materials was limited because of the lack of sufficient explanation.

Figure 4 plots the comparison of satisfaction rates for 'Tutorials in LEX. In 2009, the satisfaction rate for Tutorials was significantly lower. To unveil the reason for the worse result on tutorials, we conducted discussions with the teaching team, some tutors and students. It was reviled that most of the tutors were not familiar the visualization materials and techniques used for the first time in 2009. The tutors were not ready to provide good explanations on thevisualization materials and lacked of experience in linking the tutorial contents with visualization materials. This result tells us that to properly train tutors on the usage of visualization materials is also a crucial factor to ensure the effectiveness of visualization materials in teaching.

In summary, we have learned a lot of important information from the comparison of LEX scores. The visualization technique is a powerful tool for helping students' learning theoretical contents and abstract concepts in Dynamics subject.

However, further improvement is needed to achieve the fundamental objectives. It should be mentioned here that we will also analyze the LEX written comments from the students once they become available.

Final exam grades

Table 2 lists the comparisons of the distributions of grades and average marks for Dynamics in 2008 and 2009. It should be mentioned here that 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 2, we can clearly see that in 2009, the average mark has increased (3%). In addition, more students obtain a grade point average between 6– 7 grades (7:High Distinction, 85%-100%; 6: Distinction, 75%-84%) in 2009. It has proven that students performed better in examination in 2009, because the students had a better understanding on the teaching contents of 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 our Teaching and Learning (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 subject.

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

TABLE 2
COMPARISONS OF FINAL RESULTS FOR ENB211

CONCLUSION

The main issue and barrier in learning Dynamics subject in enginereing courses are that it includes a large amount of fundamental theoretical contents and abstract concepts. Hence, there is a huge challenge ahead on how to effectively teach Dynamics. Through our studies in 2008 and 2009, we have concluded that the visualization technique can definitely help students in learning and comprehending the abstract theories and the basic concepts of Dynamics. However, proper and sufficient explanations on all visualization contents are necessary in order to enhance students' learning of the unit. In addition, tutors play a very important role in boosting and ensuring the effectiveness of using visualization materials in teaching and learning.

As a closed cycle, for the next iteration of the action learning cycle, we have conducted the following important activities in 2010:

- We have properly trained tutors in using visualization materials; tutorial slides will be developed to ensure consistancy of all tutorials;
- We have developed detailed description and explanation on visualization files, and they have been uploaded in the on-line BlackBoard System for students' to download;
- We have developed numerous visualization materials for tutorials and computer laboratories; and
- We have used a totally new assessment sturcture to ensure that students can use visualization materials wisely and effectively.

Once the survey and examination results are aviliable, we will evaluate the outcomes of 2010 and comparing them with those results in2009 for our next activities in the next iteration.

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