Enhancing 3D Visualization for Learning Volumes of Solid, an Application in Integral Calculus

by

Rose Arienah binti Mohd Hamdan

Dissertation submitted in partial fulfillment of the requirements for the
Bachelor of Technology (Hons)
Information and Communication Technology

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CERTIFICATION OF APPROVAL

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgement, and the original work contained herein have not been undertaken or done by unspecified sources of persons.

ROSE ARIENAH MOHD HAMDAN

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ABSTRACT

Mathematics is one of the major subjects which now integrates multimedia technology to its instructional materials and has become a phenomenon all around the world. The difficulty of visualizing mathematical concepts has been one of the major factors for students who find mathematics challenging, especially in calculating volumes of solid under the topic of integration. The objective of the project is to investigate on the suitable technique to produce a 3-dimensional (3D) visualization to demonstrate volumes of solid, and to develop a multimedia courseware prototype for it. Next, is to evaluate the usability of the prototype. The focus is on the methods of calculating volumes of solid under the topic of integration, which is a topic in Calculus. A multimedia courseware using Macromedia Toolbook implementing 2D graphics has been previously developed to assist the foundation students in UTP to learn integration. To enhance the student's visualization of calculating volumes of solid, a 3D graphics multimedia courseware has been developed using the ADDIE model. The tools that are used to develop the prototype are Blender for 3D modeling and SWiSH Max 4 for layout and interactivity of courseware. Questionnaire has been distributed to get feedback from the students pertaining to 3 categories which are visualization, navigation and content. The key findings from the analysis showed that the use of video, images, graph, audio and colour in the prototype is suitable. The user experience test performed on the UTP engineering students who have taken Calculus course resulted in a positive response whereby 90% of them agreed that the use of 3D images has helped them to understand better on how to calculate the volume of solids compared to referring only to 2D graphs like what they have learned previously. 77% of the respondents also said that they would use the courseware to support their learning of Calculus.

ACKNOWLEDGMENT

Alhamdulillah, first and foremost the author would like to take the opportunity to express her gratitude to those who have been involved in completing her Final Year Project which is developed for the engineering students in enhancing their visualizations of learning volumes of solid, under the Calculus course, using 3D images.

For the two consecutive semesters, the author is very grateful to everyone who has given her the guidance, support and motivation in any possible way. The author would like to thank her supervisor, Assoc. Professor Dr. Wan Fatimah Wan Ahmad and her co-supervisor, Assoc. Professor Dr. Josefina Barnachea Janier who has monitored the progress of this project and gave the best comments and guidance in ensuring the best outcome for the development of the project.

The author would also like to thank the engineering students who has participated in the user experience testing and gave valuable feedback that is helpful for the continuous improvement of this project.

Thank you.

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CHAPTER 1
INTRODUCTION

1.1 Background Study

The rapid advancement of information and communication technology (ICT) as well as multimedia has shifted the way of learning. Nowadays, multimedia technology such as animation, graphic, sound and video is integrated into teaching to create a more meaningful learning for the students. To learn mathematics, it is essential to incorporate it with multimedia elements to make the process of learning be more interesting and relatable to real life.

Students find it hard to understand mathematics as it involves a certain degree of visualizing object in some mathematical concepts. They also need to apply formulas to calculate the certain characteristics of the object such as area and volume. Currently, there is a multimedia courseware being used by the lecturers to assist student's visualization in the topic of integral calculus, but it is only limited to 2 dimensional (2D) view only. To improve the courseware, 3 dimensional (3D) graphics and animations will be implemented in the prototype to emphasize the volumes of solid, which will yield to a meaningful learning at the student's end.

The prototype will be used and evaluated by Universiti Teknologi PETRONAS (UTP) Foundation of Engineering students who are enrolled in Calculus course. With the advancement of technology in learning environments, this 3D supported module will potentially be used in Calculus tutorial classes as well as an alternative to the conventional textbook.

1.2 Problem Statements

Students experience difficulties in visualizing some mathematical concepts such as to calculate volume of solids. Currently, the Foundation of Engineering students in UTP who are taking Calculus course are learning Integration by using the courseware provided, which have images in two-dimensional view only. This causes the students to have some problem on imagining how the object actually looks with the angles, rotation of axis, and other mathematical formulas involved. The failure rate of Calculus in UTP is about 10% and there should be corrective actions taken to reduce this rate.

1.3 Objectives

1. To investigate on the suitable technique to produce a 3D visualization to demonstrate volumes of solid.
2. To develop a multimedia courseware prototype for UTP Calculus course, which focus on three methods of calculating volumes of solid, under the application of integration topic module.
3. To evaluate the usability of the prototype.

1.4 Scope of Study and Limitations of Project

The scope of study of this project is to produce a prototype of multimedia courseware for learning a section in integral calculus, which is the volume of solid. This courseware will be used by the Foundation of Engineering students in UTP who are taking the Calculus course. Current courseware used by the students is teaching the topic of areas and volumes of solid. The focus for this prototype development is only volumes of solid by three methods using integration since calculating volumes of solid involves perspective from three different views. Current courseware used by the students are in 2D, and due to the positive response from them, a 3D visualization version of the current courseware is to be developed.

The limitations of this project is that it will only focus on producing the 3D visualization of three out of six modules (from current courseware – Macromedia Toolbook), which is Volumes of Solid by Disk Method, Volumes of Solid by

Washer Method, and Volumes of Solid by Cylindrical Shell Method. The project is limited to these three modules only due to the time constraint given to develop this project and also is to focus on the most essential 3D visualization needed in Calculus. Another limitation for this project is money. Since the money provided is not that much, tools used to develop the prototype is mostly using open source.

1.5 Benefits of Project

There are a lot of benefits of developing this project such as to allow the students to visualize the mathematical theories and objects involved in a more realistic way. It also allows the student to study at their own pace and style of learning which may vary among students as there are students who are fast learners, and some who are not, whom requires some time and more visualization to fully understand the topic. Students will also benefit from this project where they will be able to manage their own learning, as there will be features which they can be in full control of such as "Rotate about x-axis" button, "Rotate about y-axis" button, and is assisted by verbal information along their learning. If they need time to understand the mathematical theory, they can easily press one of the buttons and repeat it for as long as they wish until they understand the topic.

Besides the project being beneficial to the students, it is also a handy tool to the lecturers and tutors. Lecturers can disperse the courseware to the students in the e-Learning (an online learning portal for UTP students) and they can study it at their own, whenever and wherever they like. During the tutorial sessions, students can simply log on to the computers in the lab and access the courseware to learn about the topic and answer some questions while the tutor can be there to assist them only if the students need them. This will benefit the tutors who are sometimes not a mathematical major, and are assigned to tutor a Calculus class due to the high number of enrolment of students in a semester.

CHAPTER 2
LITERATURE REVIEW

Students have experienced difficulties in studying mathematics due to the difficulty in understanding the theories and memorizing the formulas involved (Afza et al., 2007). In order to understand the rationales behind certain mathematical concepts, students will have to visualize the picture while applying the theories and formulae involved (Wan Fatimah et al., 2008). Current methods of teaching mathematics, which are through verbal and 2D image, are insufficient for students to fully understand the topic. According to a study done to Universiti Teknologi PETRONAS (UTP) students in 2007, mathematics is said to be a creative activity for students since it involves graphs, analysis and writing formulas.

Engler et al. (2005) mentioned that mathematical concepts can be learned significantly better through visualization enhancement using computer graphics, since visualization of abstract facts can be of vital contribution to a deeper understanding of the mathematical concepts. In today's classroom scenario, teachers prefer computer-based technology to teach mathematics when teaching, as the conventional method in teaching mathematic is rather time consuming whereby teachers need to spend a lot of time in sketching rather than focusing on the application and problem solving (Rusnaini et al., 2009). Learning mathematics using technology will benefit the students and instructors tremendously. Students will be able to understand the topics easily and have the stand-by tutor available as long as they can use the computer (Chatterjee, 2008).

Yuan (2007) performed a study on the effect of integrating technology into mathematic lessons and the results on students' achievement and attitude towards mathematic. Findings showed that the technology integration has promoted a positive student attitude on their acceptance towards mathematics.

In addition, there was also a case study done by Janier et al. (2008) where she investigated and compared the effect of multimedia courseware and traditional instruction as an alternative tool for tutoring a topic under Calculus – application of integration. 50 engineering students were taken as sample and were then divided into two groups, which are group A and group B with 25 students per group. Traditional method (chalk and board) was used by Group B as the controlled group, while Group A as the experimental group used the multimedia courseware. A pre and posttests were given to determine the effects of using courseware versus traditional instruction. Report showed that the students in Group B, the experimental group, scored significantly higher on the posttest than those in controlled group. Outcome of the study also showed that the students were able to study independently using the courseware during tutorial session.

No.	Comments	Percentage (%)
1	Software tools can assist student's learning	50
2	Instructional method cannot elicit student's interest in learning	39
3	Learning methods preferred by students have changed over time	53
4	To use instructional animation that shows process of solving problems suitable to the instructional materials	72

Table 2.1 Teacher's perspective on mathematics learning

No.	Comments	Percentage (%)
1	Textbook content is insufficiently interesting	56
2	Lack of software tools to assist learning	37
3	Believe that they need of computer-assisted tools to learn mathematics	50
4	Computer-assisted tools can help them acquire knowledge in mathematics courses	80

Table 2.2 Student's perspective on mathematics learning

According to a study done by Hsieh, Shiu, Liu, Lu and Chen (2004), 50% of teachers think that "software tools to assist learning can increase the students' willingness to learn" and "lack of software tools to assist learning" may be a reason for poor learning attitudes in students. Moreover, 39% of teachers agree that "instructional methods cannot elicit student's interest in learning", and 53% suggest that "the learning methods preferred by students have changed, while instructional methods have not adjusted or changed accordingly" is the reason that students have poor learning attitudes. This shows that more than half of teachers agree with the necessity of changing instructional methods. In addition, 72% of teachers think that it would be helpful to "use instructional animation that shows the process of solving example problems suitable to the instructional materials."

At the same time, most teachers believe that computer-assisted instructional tools could visually portray and concretely explain theoretical mathematical knowledge. With regard to students, 56% agree that "textbook content is insufficiently interesting". Moreover, 37% think that "lack of software tools to assist learning" cause difficulties in learning, which reflects a certain degree of importance and necessity in developing mathematical learning software; 50% of the students believe that they need computer-assisted tools to learn mathematics; while nearly 80% agree that computer-assisted tools can help to acquire knowledge in mathematics courses. Based on the study that has been carried out, the students propose that suitable usage of mathematical assistance tools are contributing to their overall mathematics learning including verifying assignments and clarifying concepts, as well as simplifying repetitive calculation processes, allowing the focus to be centered on understanding mathematical concepts.

Multimedia has been greatly adopted into the field of education ever since the rapid development in the information and communication technology (ICT) field. "Audio, video and animation are integrated with instruction in order to create a more interesting, supportive and learning-conducive environment" (Hong et al., 2009).

Multimedia instructional environments are well-known for allowing great potential of improving the way that people learn (Sweller, 1999). In multimedia instructional environments, learners are exposed to material in a verbal manner (such as on-screen text or narration) as well as in pictorial form (including static materials such as photos or illustrations, and dynamic materials such as video or animation). Although verbal forms of presentation have long dominated education, there is encouraging evidence that student understanding can be enhanced by the addition of visual forms of presentation (Hong et al., 2009).

2.1 Theories of Multimedia Learning

2.1.1 Information Delivery Theory of Multimedia Learning

According to Mayer (1996), a straightforward theory is that learning involves adding information to one's memory. Based on this theory, the computer is a system for delivering information to learners while the teacher's role is to present the information (in words or pictures, or both). The learner's role, on the other hand, is to receive the information. For instance, when an explanation is presented in words such as narration, the learner can store the information in his or her memory. Adding pictures such as animation should have no effect on what is learned if the pictures contain the same information as the words. Therefore, according to this strict version of the information delivery theory, multimedia presentations should not result in better learning than single-medium presentations.

However, it might occur that some learners prefer visual presentations and others prefer verbal presentations, therefore, a multimedia presentation would be useful in delivering information effectively to both kinds of learners. In this way, learners could select the delivery route they prefer – visual, verbal, or even both. Thus, according to a lenient version of the information delivery theory, multimedia presentations should result in better learning than single medium presentations (Mayer and Roxana, 2002).

2.1.2 Cognitive Theory of Multimedia Learning

Mayer (1996) stated that, meaningful learning happens when students mentally construct coherent knowledge representations. The cognitive theory of multimedia learning is based on three assumptions suggested by cognitive research:

1) Dual-channel assumption – the idea that humans have separate channels for processing visual/pictorial representations and auditory/verbal representations (Pavio, 1986);
2) Limited capacity assumption – the idea that only a few pieces of information can be actively processed at any one time in each channel (Sweller, 1999);
3) Active processing – the idea that meaningful learning occurs when the learner engages in cognitive processes such as selecting relevant material, organizing it into a coherent representation, and integrating it with existing knowledge (Wittrock, 1974).

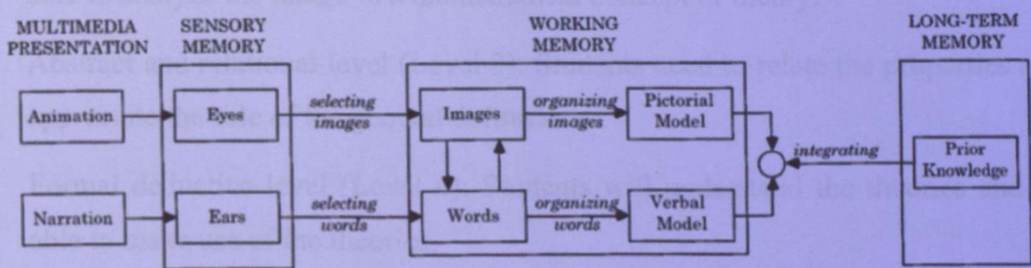

Figure 2.1 Cognitive Theory of Multimedia Learning (Mayer and Roxana, 2002).

Figure 2.1 summarizes the cognitive theory of multimedia learning that is constructed by Mayer and Roxana (2002). Narration enters via the ears, so the learner selects some of the words for further processing in the verbal channel, organizes the words into a cause-and effect chain, and integrates it with the visual material and prior knowledge. Animation enters via the eyes, so the learner selects some of the images for further processing in the visual channel, organizes the images into a cause-and-effect chain, and integrates it with the verbal material and prior knowledge. According to this theory, the cognitive process of integrating is most likely to occur when the learner has corresponding pictorial and verbal representations in working memory at the same time. Instructional conditions that promote these processes are most likely to result in a better understanding learning. This theory predicts that multimedia presentations are more likely to lead to meaningful learning than the single-medium presentations.

2.1.3 Van Hiele Model

Pierre van Hiele together with his wife, Dina van Hiele-Geldof introduced the van Hiele model of geometric thinking in 1986. They were motivated to come up with the theory from the student's problem in learning geometry and shapes (Chan and Huang, 2006). According to Luchin (2006), there are five levels in the van Hiele model, which are:

- Visual level (Level 1): The students will identify the shapes based on to the appearance, recognizing them as visual Gestalts using the visual prototype.
- Descriptive and Analytic level (Level 2): Students will have to describe and be able to analyze the image to a mathematical concept or theory.
- Abstract and relational level (Level 3): Students need to relate the properties and appreciate the role of the general definitions.
- Formal deductive level (Level 4): Students will understand the theories and be able to make use of the theories.
- Mathematically rigorous level (Level 5): Students will need to compare various theories and distinguish various shapes from the mathematical concepts.

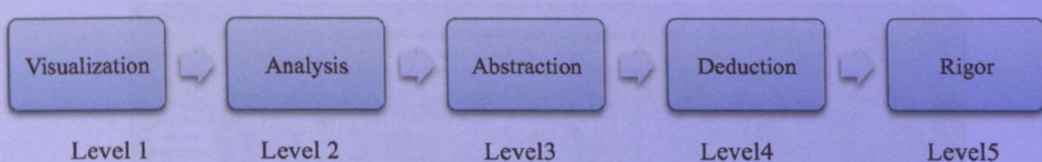

Figure 2.2 Van Hiele Model – Thinking levels

2.2 Applying 3D Visualization into Learning Materials

Objects in real life are combinations of dimensions of length, width and height. From the perspective of computer graphics, an image can be shown in either 2D or 3D forms. 3D images provide better demonstration of a figure because it is of closest to realness of the object as it can be seen from three dimensions or perspective. According to Sultana, Xuan, Cartwright, and Ailleres (2009), to construct a 3D image, the 3D modeling process is to be used. 3D modeling process is known for its accuracy in producing 3D images because the process combines several key elements from the different perspectives.

The application of 3D technology in teaching has now become a popular trend, as 3D instructional materials can effectively convey curricular content (Huang and Liao, 2008). 3D visualization and its technology allows the learners to experience visual perceptions and feelings approaching reality, which enables them to control visual points independently according to their own pace of study and learning preference, resulting in a greater understanding and meaningful learning.

2.3 Review of Current Multimedia Courseware for Calculus

The previous multimedia courseware used to teach application of integration for Calculus course in UTP is using Macromedia Toolbook. The courseware uses 2D images to depict the figures and graphs. As seen in Figure 2.3 below, to calculate the volume of the region, students need to visualize how the region looks like in a 3D view. It also states that there is a rotation about an axis based on the formula given, but in 2D view, rotation is not possible to happen. This might appear to be hard to certain students who have trouble in visualizing to a certain degree.

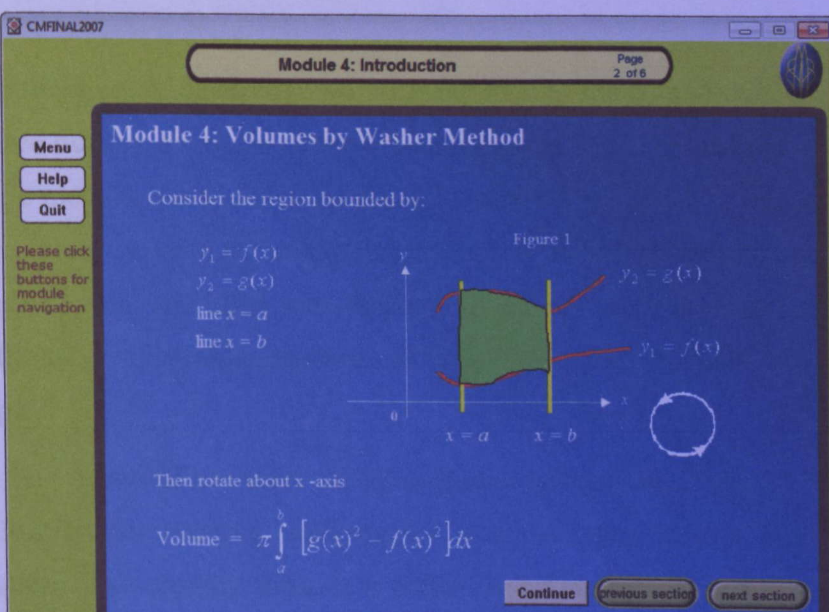

Figure 2.3 Multimedia courseware (Module 4: Volumes by Washer Method) in 2 dimensional view using Macromedia Toolbook

As seen from Figure 2.4, there are two rotations happening in the figure. It would be best if there were to have a button where the students are able to click rotate and see the effect of the rotation.

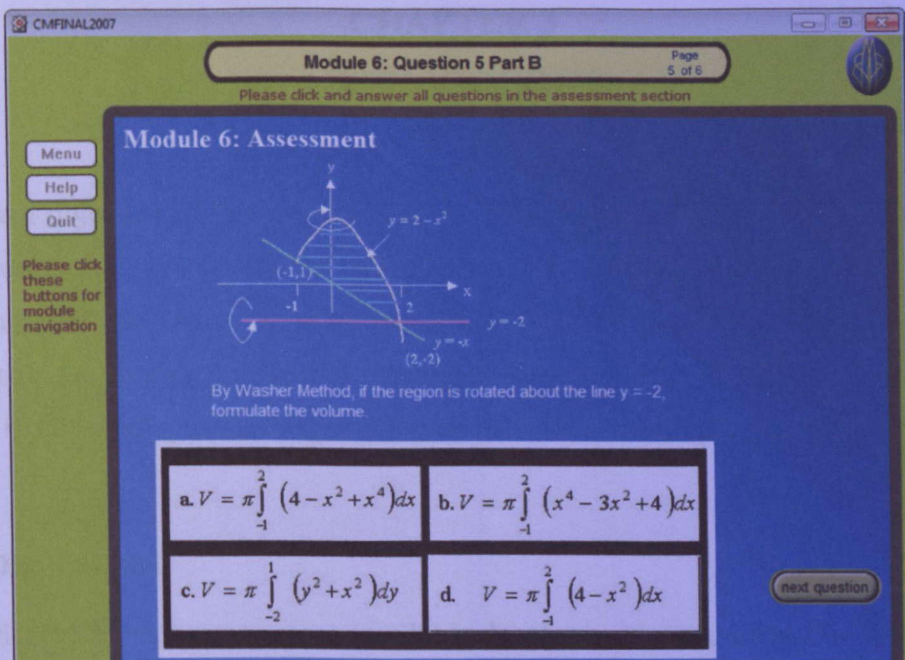

Figure 2.4 Multimedia courseware – Assessment of understanding of volume by washer method

Next is the function of the three tabs on the left side of the courseware. It states there that the three buttons are to be clicked for navigation. When a student need to jump to a specific module, for instance, when they start the courseware and would like to study on volumes of solid by washer method in module 4, they have to go through every single module and click next before they arrive to the intended page. This is not user friendly and time consuming for those who would like to concentrate on certain topics.

Based on the reviews of literature and case studies being done, it can be deduced that 3D visualization for learning mathematics is a necessary step to assist student's learning and is also moving towards a better pace than the current modules in 2D. Therefore, developing a 3D visualization for the application of integration, specifically volume of solid is essential to increase student's understanding on the topic and produces a better attitude in learning.

CHAPTER 3

METHODOLOGY

The main objective of this project is to develop a prototype which is a multimedia courseware that makes use of 3D graphics, for learning volumes of solid, an application of integration. In order to come out with the prototype, the suitable tools and technique to produce the 3D visualization needs to be identified. The ADDIE model has been adopted as the generic process flow in developing the prototype.

3.1 ADDIE Model

The selected development process model in developing the courseware is the ADDIE model. The phases involved, as seen in Figure 3.1, which are Analysis, Design, Development, Implementation, and Evaluation, each has its own purpose in fulfilling the requirements and accomplishing the objectives that has been set prior.

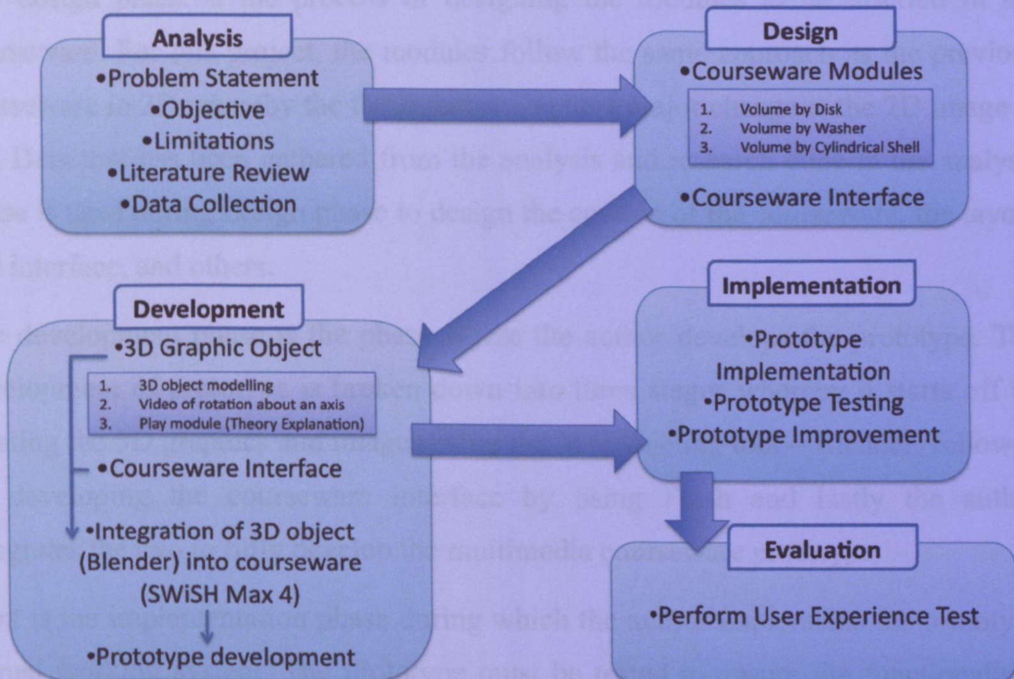

Figure 3.1 ADDIE model used for development phase

The first phase which is the analysis phase is conducted to address the issues faced by the audience. The analysis phase includes identifying the problem experienced by the targeted audience as well as finding out how to solve the problem. For this project, the author has listed out a few objectives so that the process will progress towards a focused goal. The author has also identified that only 3 out of 6 modules from the previous courseware will be used as the 3 modules which teaches volumes of solid in three methods, are the ones best depicted with 3D representations. Analysis of literature with regards to assistance of multimedia technology in learning and also 3D visualizations is performed to collect the best theories and practices that have been done previously. This will allow the author to produce the project smoothly with support and guidance from those relevant sources. From the analysis performed, the author has identified the most suitable tools and software required to build the prototype such as Blender for 3D modeling, and SWiSH Max 4 as the executable program to run the courseware.

The design phase is the process of designing the modules to be inserted in the courseware. For this project, the modules follow the same approach as the previous courseware in 2D whereby the thing that encounters major change is the 2D image to 3D. Data that has been gathered from the analysis and research done in the analysis phase is used during design phase to design the content of the courseware, the layout and interface, and others.

The development phase is the phase where the author develops the prototype. The development of prototype is broken down into three stages whereby it starts off by creating the 3D graphics and images using the 3D modeling tool – Blender, followed by developing the courseware interface by using Flash and lastly the author integrates the two to fully develop the multimedia courseware prototype.

Next is the implementation phase during which the author implements the prototype in real working system. The prototype must be tested to ensure the functionalities and features are working as planned without bugs or error. The white box testing is used to test the prototype, as the author will check coding one by one and debug it if necessary. The feedback gained from the testing is utilized for improvement before the prototype is confirmed ready to be used by the end user.

The last phase in the ADDIE model is the evaluation phase. The evaluation of the prototype, which is the user acceptance test (UAT), will be done by the end users, in this case, the students. This is to get their feedback and collect the rates given by them on the usability of the prototype.

3.2 Tools and Software Involved

3.2.1 Blender

Figure 3.2 Blender logo

After some analysis done on a few of 3D software available in the market, the software that is best to be used to create the 3D graphics in the multimedia courseware is Blender – an open package for three-dimensional modeling, animation, rendering and interactive creation, and other practical features. Blender is chosen due to several factors, which are usability, pricing, implementation-wise, and intellectual property rights.

In terms of usability, Blender is easy to use as its interface is user friendly and the commands are very well defined that makes it easy for the users especially for the beginners who are not well-versed in 3D graphic creation. Tutorials of Blender can be easily obtained online and there are a lot of forums for discussion whereby the blender masters are available to help anytime. In addition, Blender can be used and installed on any platform – Windows, Mac OS X, and Linux, which is good for portability purposes. The Blender file can also be easily exported to other creative software and programming suites such as Adobe Flash, openGL, Python, Macromedia Director MX, and many more to produce a more interactive media.

Another important factor of choosing Blender over other 3D software available in the market is due to the pricing of the software. As Blender is an open source software, no payment is needed to purchase the software and can straightly be used after being downloaded to the computer from the Internet (www.blender.org). Other options in the market are relatively pricey compared to Blender, such as Cheetah 3D – RM 310, Swift 3D – RM 460 and Autodesk 3Ds Max – RM 11000. The cost of developing this project is limited to RM 250, therefore it is a wise decision to use Blender as it still can deliver the necessary functions needed to build the project and the money allocated can be used for other important tools.

From the perspective of implementing Blender to the new multimedia courseware, based on the research done, it will not be a complicated task. For this project, the plan is to integrate the Blender 3D object file (.blend) together with SWiSH Max 4 (.swi) whereby the SWiSH Max 4 will act as the framework of the courseware and Blender will be used to present the 3D objects, which in this case is the 3D visualization of volume of solids. With the readily available feature of file exports from Blender to other file types, the task of integrating different file types would not be a hassle. This will reduce the time taken to complete the project. Furthermore, the duration given to complete the project is very short which is less than six months.

Lastly, one of the most important factor that makes Blender more attractive to use compared to the other 3D software is the property right. Blender programs created can be distributed freely to other parties and can also be licensed or sold, as the program created by Blender will become the sole property of the user or creator. This will help in commercializing the product later on whereby there should be no intellectual property claims problem encountered and it can be brought to the market easily.

3.2.2 SWiSH Max 4

For the construction of layout and interface of the courseware, the software that will be used is SWiSH Max 4. The reason the author has opted for SWiSH Max 4 is because of its fast learning curve and familiarity of author with the software especially on the Action Script. Although there are other options in the market such as Adobe Flash Professional CS5.5, due to the time constraints and lack of skill of the author, SWiSH Max 4 is seen as the better option. SWiSH Max 4 can produce the same output such as Adobe Flash and it can produce (.swf) file as well, which can be played across any platform as long as the internet browser supports Flash player.

3.2.3 Macromedia Toolbook

Macromedia Toolbook is the current courseware used to teach Calculus which is in 2D form. The new courseware prototype that is to be developed is used in the early stage of design and development phase to extract modules 3, 4 and 5 from the current courseware. Modules 3, 4 and 5 from Macromedia Toolbook will then be enhanced and replaced with the new courseware prototype by the name modules 1, 2 and 3 respectively. The 2D images as seen in the Macromedia Toolbook will be replaced by 3D graphics along with rotation feature to allow better visualization of solids in application of integral calculus.

3.3 Activities

Activities that needs to be carried out in order to gather the data for this project is to perform an evaluation on the effect of 3D visualization in learning volumes of solid, an application in integral calculus, to the UTP Foundation of Engineering students who already took the Calculus course.

3.3.1 User Experience Test

An evaluation or study will be carried out in the second half of project development phase. A set of questionnaires will be handed to the students to find out their experience when using the prototype. The questions are to be graded with satisfaction ranks (1-strongly disagree – 5-strongly agree) and given out to the students for them to rank on the usability of the prototype for instance, how the 3D images can help them visualize better, user-friendly layout and suitability of audio tone used. The result of this survey will then be calculated to be analyzed and determine the usability of the prototype created as well as for the feedback gained, should there be corrective measures taken to enhance the prototype or not.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 System Prototype

4.1.1 Main Page

The prototype's user interface begins with main page showing the title of the prototype which is "Calculating Volumes of Solid: An Application of Integration". Should the user would like to skip this page, they can directly click the green circle button "Enter", or the page will automatically redirect the user after 5 seconds to the next page which contains the list of modules. At the list of modules, the user can choose which module that they would like to study on and simply click on one of the boxes.

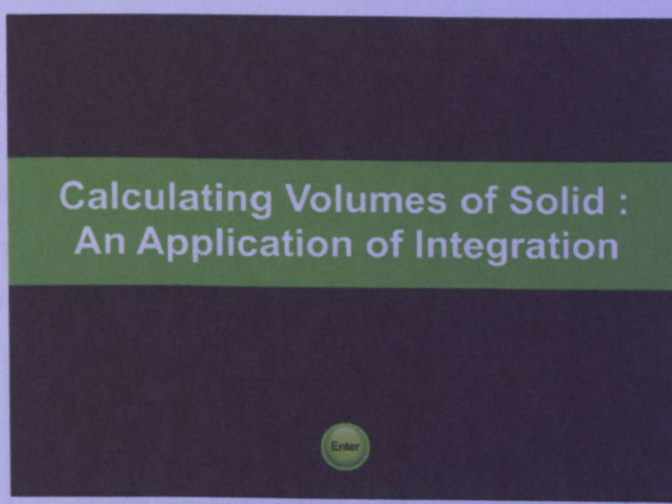

Figure 4.1 Main page – Part 1

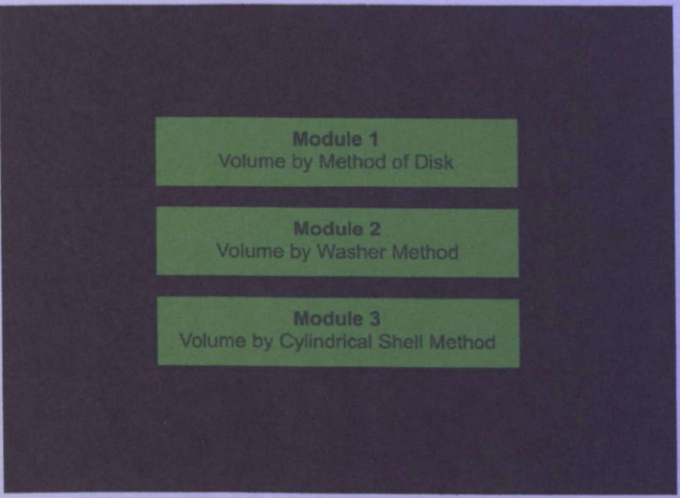

Figure 4.2 Main page – Part 2

4.1.2 Modules

There are three modules available for calculating volumes of solid under the topic of integration, which are Module 1 – Volume by Method of Disk, Module 2 – Volume by Washer Method, and Module 3 – Volume by Cyllindrical Shell. At the beginning of each module, there will be an objective statement for the users to achieve by the end of their learning. For instance, in Module 1, there are two parts of introduction, Introduction 1 – for Regular Shaped Solids and Introduction 2 – for Irregular Shaped Solids. Users will click on the grey buttons according to their preference on which part that they would like to study on. If the user needs to repeat, they can click on the buttons again and the modules will repeat the instructions. While going through the modules, a narrator's voice will explain the steps to be taken for a particular mathematical formula to make the learning more interactive.

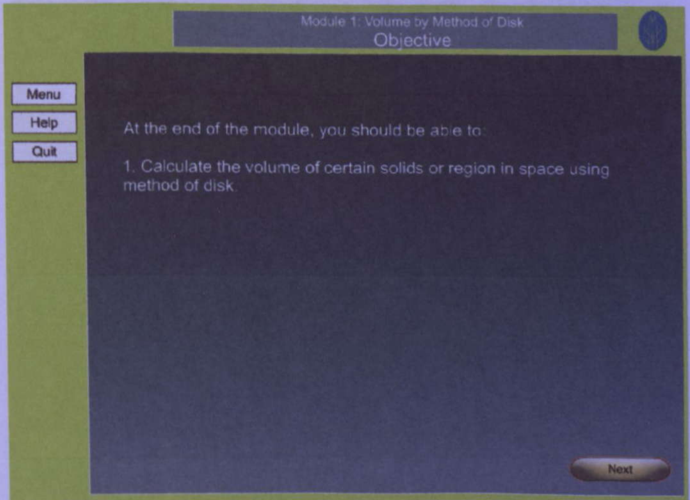

Figure 4.3 Module 1 – Objective

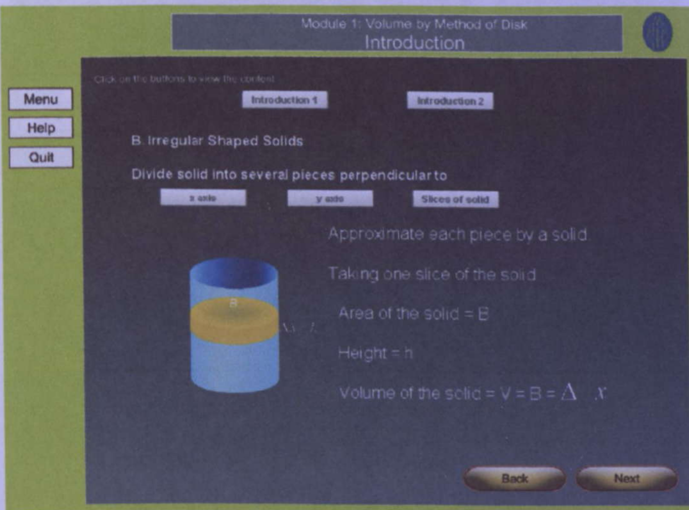

Figure 4.4 Module 2 – Introduction

After the introduction, the users can click on "Next" button to proceed to the procedure subtopic where it teaches several procedures on calculating the volumes of solid based on the particular method in the respective modules. Users just need to click on the grey buttons and view the different procedures available. 3D images or videos will be available and is situated beside the 2D graphs to show how a volume is formed by revolving the region about a particular line or axis. The 3D videos are on loop so that the users do not have to click on replay many times. The solution of each example will be given after the 2D graphs and 3D videos have appeared on screen. avigation through each subtopic

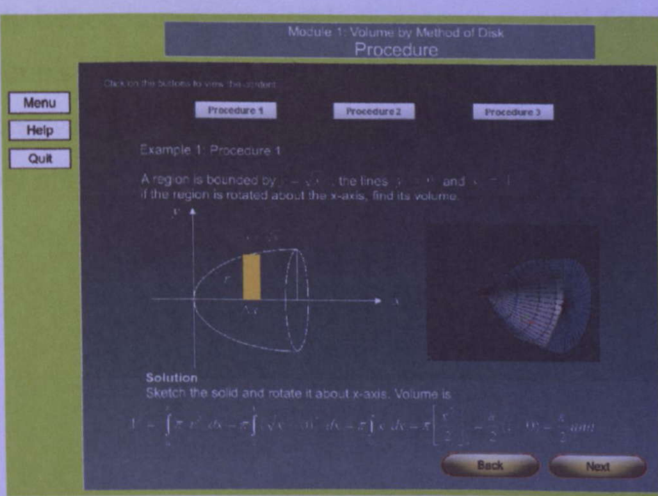

Figure 4.5 Module 1 – Procedure

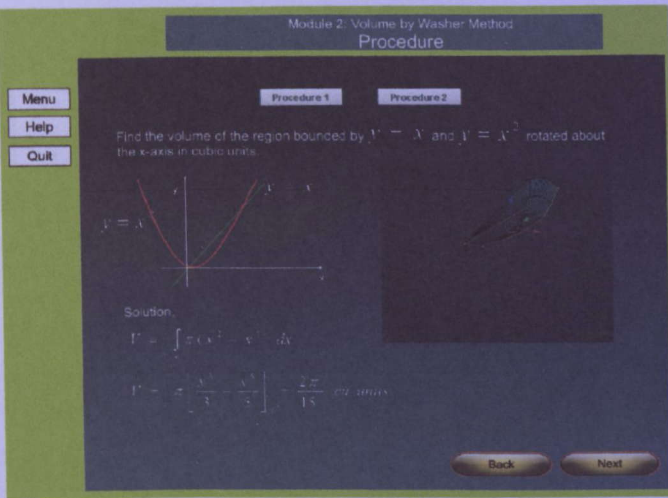

Figure 4.6 Module 2 - Procedure

4.1.3 Navigation

The navigation through the courseware is simple as it uses a minimum number of buttons and is situated only at two positions, the left hand side and at the bottom right of the screen.

At the left hand side, there are Menu, Help and Quit buttons for the users ease of access. The Menu button will showcase the list of modules together with the direct extensions to Objective, Introduction or Procedure. By having this Menu, users do not need to browse the courseware by clicking "Next" or "Back" continuously until they reach their intended module.

In addition, a Help button is made available to act as a manual for the users to assist them with navigations of the courseware. There are explanations on the use of each button in the courseware for the users to better understand. Meanwhile, clicking the Quit button simply means exit and the program will be terminated.

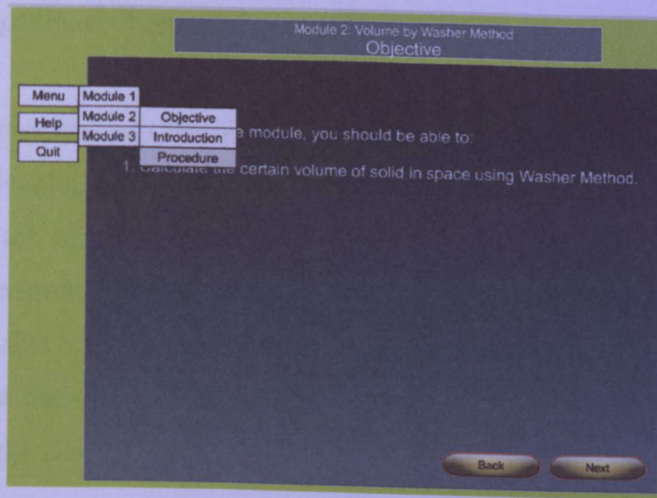

Figure 4.7 Menu button

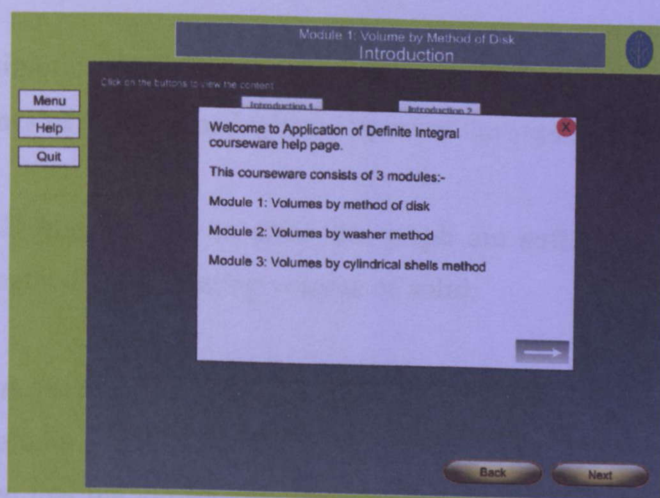

Figure 4.8 Help button

4.2 *User Experience Test*

The user experience test was handed out to 35 students to analyze their opinion about the prototype developed. Based on the questionnaire given (as attached in the appendix), the set of questions represents three criteria of usability which are visualization, navigation and content. As shown below are the results of the testing and the analysis that has been made by the author from the test conducted. The scale used to measure the data is likert scale whereby it is a 5 level scale, with 1 to represent Strongly Disagree, 2 – Disagree, 3 – Fair, 4 – Agree, and 5 – Strongly Agree.

Visualization

This category signifies the effectiveness of 2D and 3D images used to show the graph and volumes of solid formed which improves the student's visualization.

Question 1: 2D images used to show the graph are sufficient to understand the method of calculating volume of solid.

Based on the first question, which asks on the students ability to understand methods of calculating volume of solid just by using 2D images in the courseware, 13 out of 35 students agree that the 2D images used throughout the courseware are sufficient for them to understand the methods of calculating volumes of solid. The 2D images are shown in terms of graph with different colours to distinguish equation of lines and regions bounded by the lines.

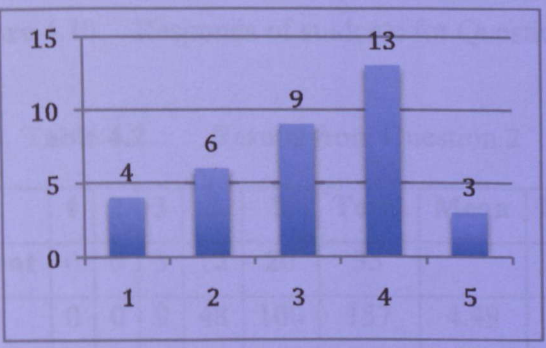

Figure 4.9 Responds of students for Question 1

Table 4.1 Results from Question 1

Items	1	2	3	4	5	Total	Mean	Percentage (%)
No of Respondent	4	6	9	13	3	35		
Weightage	4	12	27	52	15	110	3.14	62.86

Question 2: The use of 3D images improves visualization of the volume of solid formed.

From the second question, with regards to the investigation on the effectiveness of 3D images used to form volume of solid, it can be seen that majority of the students strongly agree that the 3D images or videos used in the courseware improves their visualization of formation of solid when it is rotated about a certain line or region. The mean score of 4.49 is significantly high with no respondents saying that the 3D images did not improve their visualization. This shows that all of the respondents had a better visualization of volume of solid formed with the help of 3D images rather than only 2D images to assist their learning.

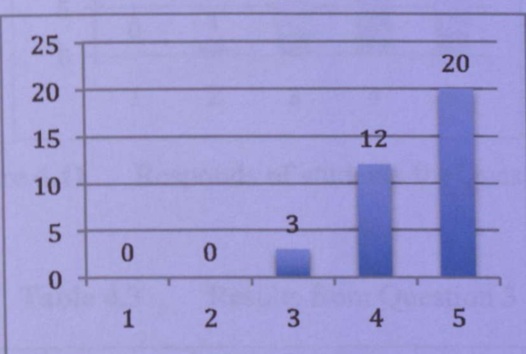

Figure 4.10 Responds of students for Question 2

Table 4.2 Results from Question 2

Items	1	2	3	4	5	Total	Mean	Percentage (%)
No of Respondent	0	0	3	12	20	35		
Weightage	0	0	9	48	100	157	4.49	89.71

Navigation

This category is about the easiness of the user in browsing through the courseware with the functions provided such as help and next, back, or continue buttons.

Question 3: It is easy to navigate through the courseware.

The third question in the user experience testing gives a statement that it is easy to navigate through the courseware. 21 students agree and six students strongly agree that the courseware is easy to navigate. This is true due to the fact that the author uses a simplistic and standardized design throughout the whole courseware so that the user do not experience any complication while doing so. The mean score is 3.91 which is in range between fair and agree, but it is very much towards agree.

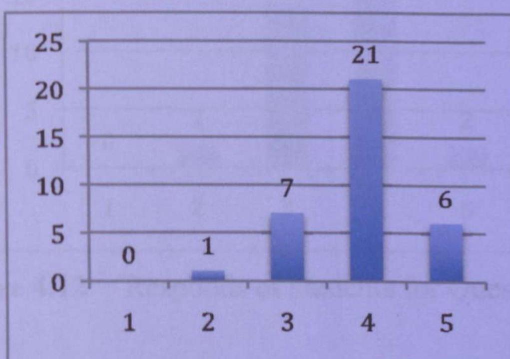

Figure 4.11 Responds of students for Question 3

Table 4.3 Results from Question 3

Items	1	2	3	4	5	Total	Mean	Percentage (%)
No of Respondent	0	1	7	21	6	35		
Weightage	0	2	21	84	30	137	3.91	78.29

Question 4: The help function is explanatory.

The help function acts as a manual of the prototype for the users to use if they need guidance in exploring the courseware especially for the first time users. From the survey gathered, the mean of 3.54 shows that the users do not quite agree that the help function is explanatory enough to enlighten them on how to use and navigate through the courseware. Although the percentage of satisfactory level of the user is high, 70.86%, the help function should be improvised, as it is one of the important functionalities of any system. Among the feedback received from the respondents are that the help function is too brief as it is all gathered in one pop-up area and is recommended to do a step-by-step manual for better understanding.

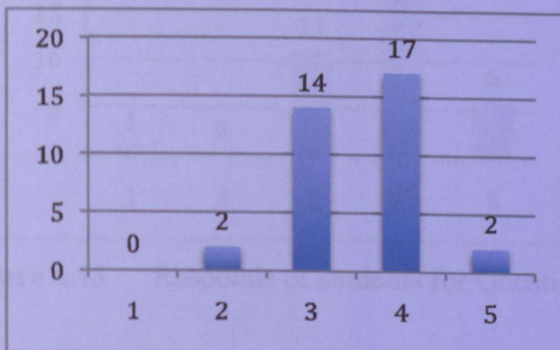

Figure 4.12 Responds of students for Question 4

Table 4.4 Results from Question 4

Items	1	2	3	4	5	Total	Mean	Percentage (%)
No of Respondent	0	2	14	17	2	35		
Weightage	0	4	42	68	10	124	3.54	70.86

Question 5: Easy to move to different module pages using the buttons provided.

The next question asked to the students is with regards to the easiness of user to go to different modules using the buttons provided at the bottom of the courseware as well as using the menu button located at the left hand side of the courseware. With the total percentage of 75.43%, it is seen that majority of the students find it easy to move through the modules using the buttons provided, but there are quite a number of feedbacks from the students pertaining to the buttons used. They claim that the buttons are a bit confusing, specifically between the "Next" button which is actually to proceed to next subtopic or topic, and the "➔" button to continue current instruction in a particular subtopic. The author has acknowledged this matter and necessary amendments are made to make the prototype better.

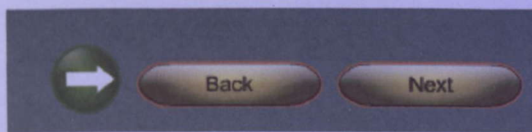

Figure 4.12 Buttons to navigate to different sections of modules

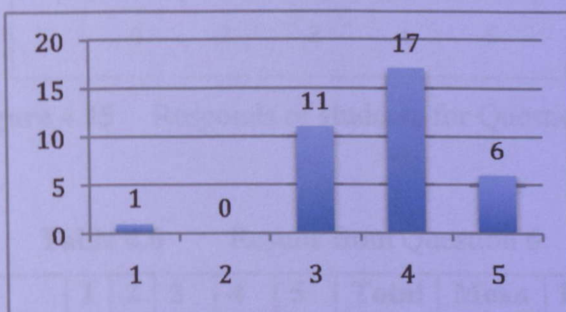

Figure 4.13 Responds of students for Question 5

Table 4.5 Results from Question 5

Items	**1**	**2**	**3**	**4**	**5**	**Total**	**Mean**	**Percentage (%)**
No of Respondent	1	0	11	17	6	35		
Weightage	1	0	33	68	30	132	3.77	75.43

Content

This category consists of several criteria such as sentences used, font, audio, and colour that together make up an informative content for the courseware.

Question 6: Introduction of each module is clear and concise.

For each module, there is an introduction which informs the students briefly on the methods used to calculate the volume of solids. The response received from the students is in the range of fair to agree. With the mean score of 3.60, it can be deduced that the contents in the introduction appears as just fair to the user as they do not agree much that it is clear and concise. Some students mentioned that the introduction is too brief and general that they find it not helpful, and there are students that mention the animations used are too fast causing them to not concentrate on the important mathematical steps shown.

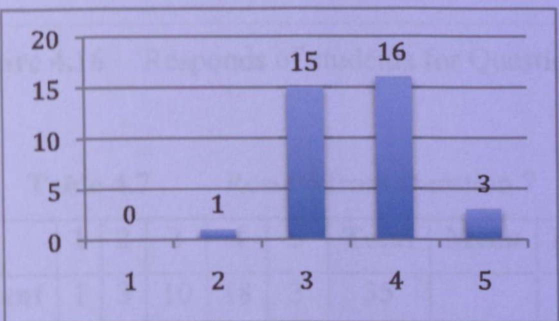

Figure 4.15 Responds of students for Question 6

Table 4.6 Results from Question 6

Items	1	2	3	4	5	Total	Mean	Percentage (%)
No of Respondent	0	1	15	16	3	35		
Weightage	0	2	45	64	15	126	3.60	72.00

Question 7: Procedures in each module are satisfactory.

There are two to three procedures provided in each module according to the Calculus syllabus provided. For each procedure, there is at least one example on how to apply the method of calculating the volume of solid using the mathematical equations given. This criteria of the survey shows a mean of 3.54 with majority of the students agreeing that the procedures are satisfactory. Despite the majority number, there are about one-third of the students who suggests that the amount of examples in the procedures to be more as it is the most important part in the topic for them to understand better.

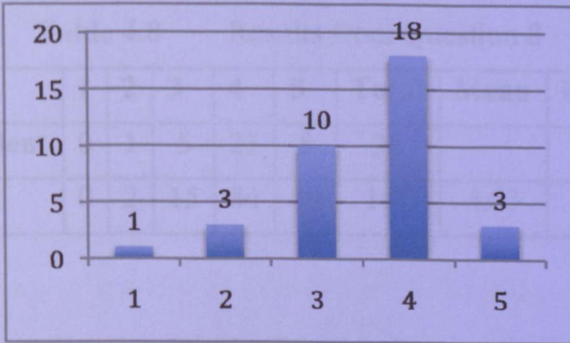

Figure 4.16 Responds of students for Question 7

Table 4.7 Results from Question 7

Items	1	2	3	4	5	Total	Mean	Percentage (%)
No of Respondent	1	3	10	18	3	35		
Weightage	1	6	30	72	15	124	3.54	70.86

Question 8: Font size and spacing are easy to read.

As for the font size and spacing of paragraphs used in the courseware, the percentage is high (80.57%) with the mean of 4.03 which shows average of students agree that the font size and spacing is readable. The one student who responded disagree gave a comment that it would be better if the font was slightly larger and to use black fonts instead of white.

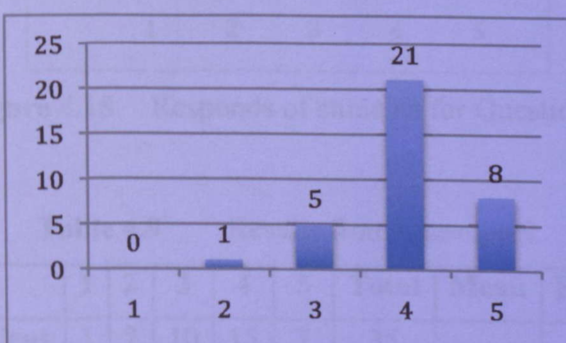

Figure 4.17 Responds of students for Question 8

Table 4.8 Results from Question 8

Items	1	2	3	4	5	Total	Mean	Percentage (%)
No of Respondent	0	1	5	21	8	35		
Weightage	0	2	15	84	40	141	4.03	80.57

Question 9: The tone of voice used to describe the modules is suitable.

From the initial testing, there was a high amount of comment suggesting that voice should be included to support the instructions and mathematical steps in the modules. Due to that, the author has come up with narration of the modules. Based on the user experience testing performed, the mean score for the particular criteria is 3.71 and a high percentage of 74.29%. It is agreed that the tone of voice used is fairly suitable. There are comments such as the tone of voice is too boring and sounds like in lectures, and suggests more fun and exciting tone of voice to get the students mood positive for a more enjoyable learning.

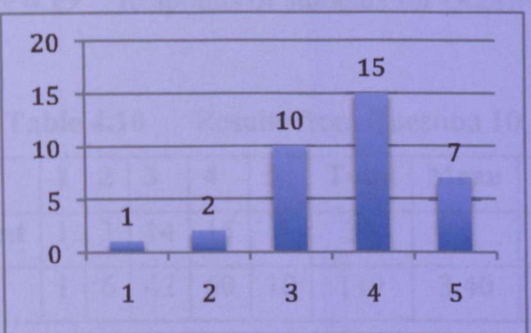

Figure 4.18 Responds of students for Question 9

Table 4.9 Results from Question 9

Items	1	2	3	4	5	Total	Mean	Percentage (%)
No of Respondent	1	2	10	15	7	35		
Weightage	1	4	30	60	35	130	3.71	74.29

Question 10: The colour theme used in the courseware is acceptable.

Question 10 tests on the acceptance of the user on the colour theme used in the courseware which is army green as the frame layout and grey as the colour for content box. The font used is white as it is contrasting of the colour grey. The mean of 3.40 from the result of the survey shows that the students think that the colour used is acceptable in a fair statement but not agreeing on it too much. Many of the issues raised on the colour theme is that the colour used is not bright and it should be contrasting of the colours used on fonts, graphs, images, and others.

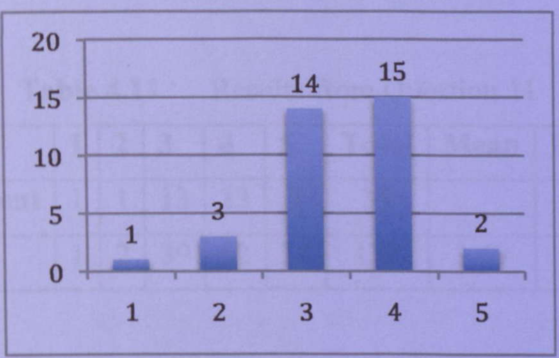

Figure 4.19 Responds of students for Question 10

Table 4.10 Results from Question 10

Items	1	2	3	4	5	Total	Mean	Percentage (%)
No of Respondent	1	3	14	15	2	35		
Weightage	1	6	42	60	10	119	3.40	68.00

Question 11: Colours used to differentiate objects (lines, axis, solid) in the graphs are helpful.

The survey also inquires on their opinions of the colours used for different objects in a graph. The author uses distinctive colours for each lines, axis, and the regions in the graph so that users will distinguish the variables better. 73.71% of them agree that the diversified colours used in the graphs are helpful, while there are two of them that disagree on the effectiveness of using different colours to assist their learning.

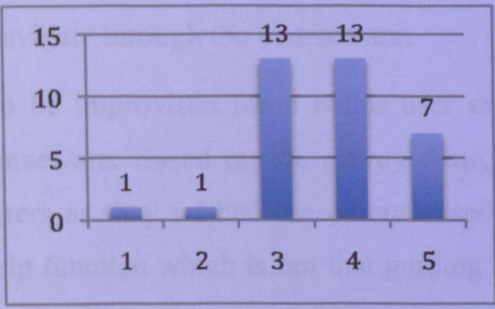

Figure 4.20 Responds of students for Question 11

Table 4.11 Results from Question 11

Items	**1**	**2**	**3**	**4**	**5**	**Total**	**Mean**	**Percentage (%)**
No of Respondent	1	1	13	13	7	35		
Weightage	1	2	39	52	35	129	3.69	73.71

Based on the overall result of user experience testing performed on the 35 engineering students, it can be clearly seen that the user is most satisfied with the 3D images used to improve visualization on formation of volumes of solid with the highest mean of 4.49. This proves that the objective of the project in investigating the techniques to produce 3D visualization and developing the multimedia courseware to demonstrate volumes of solid as a success.

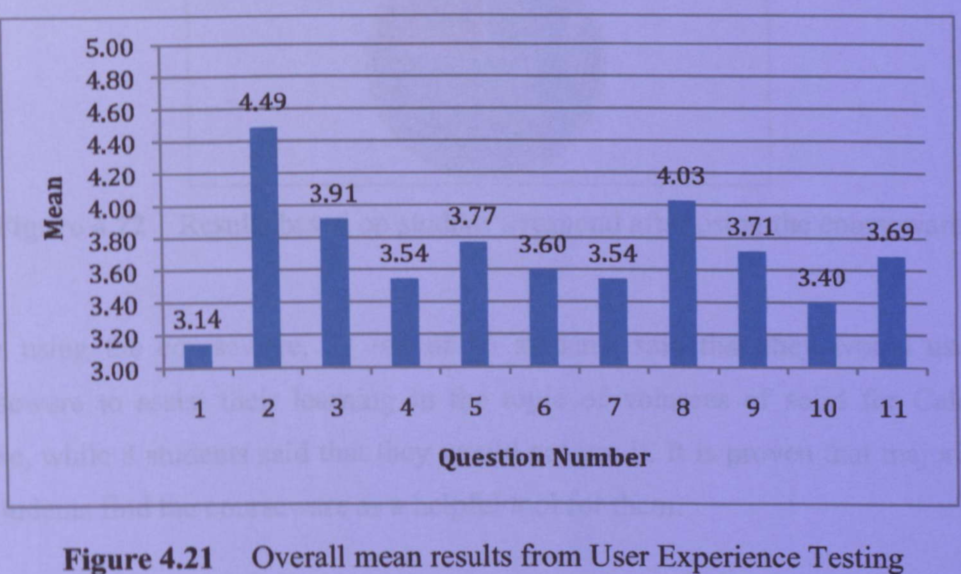

Figure 4.21 Overall mean results from User Experience Testing

Other than that, among the top scorings for the mean is question 8 with a mean of 4.03, on the font size and spacing used, as well as a mean of 3.91 for question 3, on the easiness of user to navigate through the courseware.

The things that need to be improvised for a better user experience is firstly, the colours used in the courseware. Based on the survey done, the colour used is not appealing to a lot of users as they wished the colours used are brighter and more contrast. Next, is the help function which is not that guiding for the users as it is too brief. The improvement should be to put a step-by-step manual to assist those who click on the help button especially the first time users. Lastly, is the content of the procedures, whereby the students would like to have more detailed explanation and more examples of the methods to calculate the volume of solid. They also mentioned on including quizzed or exam questions after each module to make their learning more meaningful. As the author had to follow the modules based on the syllabus that has been given to her in developing the courseware, she has no authority to add on items in the courseware. In addition, the time limitation of the project development is one of the major factors that hinder the author to contribute more to the project as the time to develop it with elaborate content such as quizzes or exam questions will be longer.

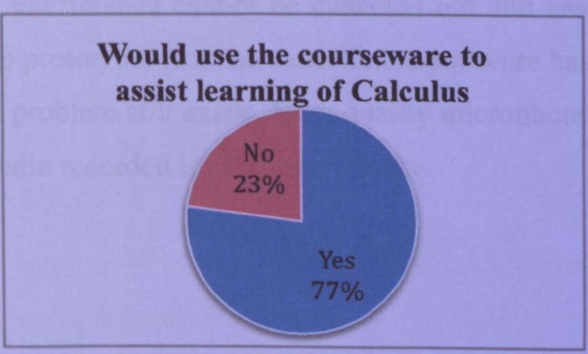

Figure 4.22 Results based on student's respond after using the courseware

After using the courseware, 27 out of 35 students said that they would use the courseware to assist their learning in the topic of volumes of solid for Calculus course, while 8 students said that they would not use it. It is proven that majority of the students find the courseware as a helpful tool for them.

4.3 Challenges faced when developing the prototype

After the process of designing the interface and modeling of the 3D objects to be used in the courseware, there are several challenges faced by the author when developing the prototype. The problems are listed as per below.

1. **Cannot export 3D files from Blender to Flash**

   There is a difficulty of exporting the 3D models from Blender with file extension .blend into the courseware interface which uses SWiSH Max 4. The .blend file needs to be rendered into animation first and only then can be embedded in the Flash software for building of courseware contents. The method of having video animation can solve the problem but it is not similar as what the author has targeted to achieve earlier on so that it can be seamlessly integrated and manipulated directy by user. The author had to proceed with the video animation showing a certain degree of rotation of the 3D project as the issue of directly exporting 3D files into Flash cannot be resolved especially due to the limited amount of time.

2. **Audio with noise interference in the prototype**

   The use of audio to act as narration of the modules is one of the critical inputs of this project. As the author uses only a normal microphone to record the voice, noise interference cannot be canceled out and has affected the audio quality of the prototype. A noise cancellation software has been used to solve the issue but problem still exists. High quality microphones should be used to ensure the audio recorded is at its best quality.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

It has been identified that Calculus is one of the toughest course in university. From a study conducted in UTP, the topic of calculating volumes of solid in application of integration has been identified as the hardest topic in Calculus course. This is probably due to the difficulties in visualizing objects and the related mathematical concepts involved. From the analysis of literature that has been done as well as the review of the previous multimedia courseware used to teach integration, it is deduced that multimedia has played a significant role in the process of learning mathematics. It is also known that the emergence of 3D technology is an essential tool in learning mathematics especially those involving depicting volumes of an object which requires three different perspective views.

From the previous courseware used by the students in UTP to learn calculus, 2D images are still not that helpful as there are a number of students who have problem with visualizing to a certain degree. Due to this issue, it is necessary to address the need of enhancing the 3D visualization in learning volumes of solid, under the topic of application of integration.

The development model used in this project is ADDIE model as this project is focusing on developing an educational prototype which requires proper analysis and design, as well as suitable development methods and evaluation. Tools that were used by the author to produce this project are Blender for 3D modelling and rendering, and SWiSH Max 4 for the layout and interactivity of courseware.

The user experience test performed on the UTP engineering students who have taken Calculus course resulted in a positive response whereby 90% of them agreed that the use of 3D images has helped them to understand better on how to calculate the volume of solids compared to referring only to 2D graphs like what they have learned previously. 77% of the respondents also said that they would use the courseware to support their learning of Calculus. It can be deduced that the objectives set earlier has been met and there are several recommendations to further improve this project.

5.2 Recommendations

Currently, there are limitations to the courseware that has been developed due to the constraint of time, money and resources. In order to fully achieve the objective of this calculus courseware, there are several recommendations that can be taken into account to enhance the prototype.

1. 3D object models integrate seamlessly into courseware's interface

   The 3D object models should be able to be imported directly into the courseware so that manipulation of the object can be done such as rotation to certain extent of degree, rotation about an axis, and walkthrough of the 3D objects so that the students can imagine it better with a wider range of view since they can choose and control what they want to see. The user should also be able to input equations as they wish and the 2D graph as well as 3D object will change accordingly based on the input. They can also repeat the steps several times until they fully understand the concept. Currently, the prototype can only embed video animation, which is prerecorded whereby the objects are rotated 360°.

2. Video of a teacher explaining in a window in the courseware

   The courseware developed can be improvised by adding another feature which is the video of a teacher explaining to the students in a static window in the courseware. This is to accommodate the different learning styles of each student. Some might be able to understand the concepts taught in the courseware just by going through it, but some might require a visual of a teacher explaining it to them, just like the traditional method of teaching.

3. Develop an online version of the courseware

   It is also recommended to develop the online version of the courseware. This is because of the advancement of technology nowadays which is moving towards mobile and tablet applications. Students need not bring around the

CD and laptop to use the courseware, whereby they just need to log on to the particular website and they are able to learn on the go.

4. Include a peer-to-peer game section in the courseware.

   To increase the interactivity of the courseware, it is a great idea to add on a game feature in the courseware whereby students can compete with their peers when answering the quizzes at the end of each module. They can also assist their peers by giving tips to answer the questions. The existence of game or role play in learning has become a popular trend as it is a fun and interactive way to acquire knowledge. This game idea can be done through interconnection between local area networks (LAN) which are used widely in universities, as well as putting it up online where the students will need to connect to the specified servers.

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FYP: Enhancing 3D Visualization for Learning Volumes of Solid, an Application in Integral Calculus.
User Experience Test – 2.0

Kindly tick at the necessary columns based on the criteria given.

	Strongly disagree	Disagree	Fair	Agree	Strongly agree
Visualization					
2D images used to show the graph are sufficient to understand the method of calculating volume of solid.	❍	❍	❍	❍	❍
The use of 3D images improves visualization of the volume of solid formed.	❍	❍	❍	❍	❍
Navigation					
It is easy to navigate through the courseware.	❍	❍	❍	❍	❍
The help function is explanatory.	❍	❍	❍	❍	❍
Easy to move to different module pages using the buttons provided.	❍	❍	❍	❍	❍
Content					
Introduction of each module is clear and concise.	❍	❍	❍	❍	❍
Procedures in each module are satisfactory.	❍	❍	❍	❍	❍
Font size and spacing are easy to read.	❍	❍	❍	❍	❍
The tone of voice used to describe the modules is suitable.	❍	❍	❍	❍	❍
The colour theme used in the courseware is acceptable.	❍	❍	❍	❍	❍
Colours used to differentiate objects (lines, axis, solid) in the graphs are helpful.	❍	❍	❍	❍	❍

Would you use the courseware to assist your learning for the topic in Calculus? (Yes / No)

Please give some feedback or suggestions to improve the prototype:

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