CHAPTER 1

INTRODUCTION

1.0 Introduction

Advances in telecommunications technology have created new possibilities for learning across the boundaries of time and place (Bruner, J.S. 1979). What is now known about learning provides important guidelines for the uses of technology that can help students and teachers develop the competencies needed for the 21st century. Inappropriate use of technology can hinder learning – for example, if students spend most of their time picking fonts and colors for multimedia and reports instead of planning, writing and revising their ideas (Dunham, P.H. 1994).

Attempts to use technologies to enhance learning began with the effort of pioneers such as Atkinson and Suppes (Atkinson 1998). The computer technology trend will continue to accelerate. The view of technology is that its presence in schools will enhance student learning and achievement. Several groups have received the literature on technology and learning and concluded that it has a great potential to enhance achievement and teacher learning, but only if it is used appropriately (Bruner, J.S. 1979).

1.1 Project Details

1.1.1 The aim of the project is to integrate the pedagogical aspect with the technology in terms of the content, instructional design, interface and interactivity in learning Mathematics courseware development focusing on Quadratic Function for form four students.
1.1.2 Objectives:

1. To research how Cognitive Load Theory can support learning and understanding Mathematical concept.

2. To design and develop a prototype on Mathematics courseware based on the Cognitive Load Theory method in an interactive environment.

3. To evaluate the feasibility of supporting student learning using CLT based prototype.

1.1.3 Problem Statement

Coursewares nowadays focus too much on a multimedia content whilst overloading the information that can be absorbed by users. Currently it is estimated that 75% of today’s industry are focusing on Mathematics due to the most important subject in school. Teaching and learning Mathematics in many Malaysian schools have been reported to be too teacher centered and that the students are not given enough opportunities to develop their own thinking skills (Goh, C. & Taib, Y. 2006). However, without appropriate teaching method used, this subject become very difficult to understand and comprehend. Many students are not able to comprehend what their Mathematics teachers teach because the content is taught with the intention of finishing the syllabus and preparing for the examinations.

There are many techniques that can be learnt to help students gain attention towards the subject. Traditional teaching approaches emphasizes more on how much the students can remember and less on how well the students can think and reason. Thus learning
becomes forced and seldom brings satisfaction to the students. In addition, Mathematics is traditionally thought of as memorization of formulae, the long and monotonous computation and the manipulation of numbers. It is also tradition that rules that the tools to computing and manipulating Mathematics are the pencil and paper. Finally it is also thought that the conventional way of delivering lessons is the chalk and talk method (Idris, N 2002).

The multimedia technology used in the learning courseware has the capability to combine and integrate various media like graphics, sound, text and animation making it is more meaningful and effective learning tool. Students generally have difficulty in understanding mathematical concepts because mathematics has not been introduced in a holistic approach. Mathematics has generally been introduced in isolation to the lives of the students as a whole, thus making learning Mathematics a meaningless as well as a dull experience. Realizing this problem, the research will need to identify a suitable theory to learn Mathematics in schools using the multimedia technology through the courseware. Hence, the researcher aware other potential subject but for this particular research, Mathematics will be used as the subject.

CLT states that learning can be maximized by ensuring that as much of a learners’ working memory as possible is free to attend solely to encoding to-be-learned information (Sweller 2002). In the current software, student need to solve or practice many problems solving to learn because ‘practice make perfect’, but in this particular courseware, students learn by studying worked-examples. Problem solving is used to test if learning has been effective. The success of CLT in developing strategies and techniques which result in both reduced training times and enhanced performance is of
paramount importance to the education. For example, in CLT application courseware, it uses goal-free problem whilst in the current courseware it still use the conventional problems which specify the goal so that students ‘know what they have to find’.

1.1.4 Project Significance

Mathematics courseware can be used as an additional reference material by students outside the classroom or beyond the school period. In addition, this courseware follows the school syllabus and therefore teachers would not have to worry about the content of this mathematics courseware.

The prototype cover on the topic of Quadratic Function and it is not only suitable for teachers to use it to enhance their teaching skills, but most importantly, it can be used by students for individualized and self paced learning. Hence, the courseware designed based on the Cognitive Load Theory method.

Cognitive Load Theory influence the design of the current multimedia-aided learning application:

- Multimedia-Aided Learning aim to provide learners with both rich set of learning resources and tools to help them navigate throughout the courseware.

  The Computer-Based Training is a method used in this particular research where based on CLT, evidence for learning by studying worked-example is known as worked-example effect and has been found to be useful in many domains such as physics, mathematics or programming to (Giller, S. & Barker, P. 2004),

- Mayer (1997) agreed that learning can be enhanced by displaying the graphic images and voice over concurrently with the text. Cognitive Load methods can
be used for improving the instructional efficiency of interactive learning materials.

- As Mayer (1997) stated in his theory that the screen itself should be designed by the designer either with pictorial or text in order to make the courseware understandable.

This study enables greater participation from instructional or courseware designers and allows the designers to identify and improve areas of the courseware developed for the learners. In addition, this research can also serve as a basis for other courseware subjects such as science, physics, etc to implement the theory.

Furthermore, the results of the study aim to inform theory and practice that can be used to assist instructional or courseware designers to reduce the load caused by poor design of the learning materials. Therefore, the findings can be used to provide opportunity to make improvement to the courseware such as producing an easy to learn courseware and ensure the users are able to understand and process information to improve their performance, knowledge and skills.

Mathematics was chose as the research subject because this is one of the subject that need more memory load of human brain or thinking. According to Giller, S. & Barker, P. (2004), evidence for learning by studying worked-example is known as worked-example effect and has been found to be useful in many domains such as physics, mathematics or programming.

In this particular courseware development, the theory proposed by Mayer (1999) is used, that is the screen itself is designed either with pictorial or text in order to make the
content understandable. Furthermore, by displaying the graphic images and voice over concurrently with the text, it can reduce the cognitive load of the users.

1.1.5 Project Scope

This Mathematics courseware mainly focuses on the higher secondary level, form four students to be exact. For this dissertation, the topic chosen is Quadratic Function. Quadratic Function is one of the important topics for Mathematics syllabus. In addition the subject requires a good teaching technique to attract attention from the students hence, minimize the working memory. After considering the importance of this topic, the Cognitive Load Theory (CLT) is proposed. The courseware is developed to see the effectiveness of the CLT. The courseware has incorporated interesting and colorful graphics as well as animation to enhance students’ interest on the lesson taught.

The courseware adopts the perpetual navigational approach instead of sequential navigational approach, which helps students use the courseware more effectively as they are constantly aware where they are in the program. Moreover, the interactivity part of the system ensures that the student is actively participating in the learning process. The interactive approach to the exercises also means that students are able to obtain feedback from the system as to whether they are correct or otherwise, immediately. The system is able to show the correct method to solve a certain mathematical problem if he or she goes through the revision module. In addition at the end of the courseware, there will be a brief summary on the subtopics. The screen shot can be viewed in Chapter 4.
Table 1.1: Gantt Chart for CLT Based Model in Mathematics Software

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>RESEARCH</td>
<td>180 days</td>
<td>Tue 7/1/08</td>
<td>Mon 3/5/09</td>
</tr>
<tr>
<td>ANALYSIS</td>
<td>38 days</td>
<td>Mon 9/29/08</td>
<td>Wed 11/15/08</td>
</tr>
<tr>
<td>DESIGN</td>
<td>65 days</td>
<td>Mon 11/3/08</td>
<td>Fri 1/30/09</td>
</tr>
<tr>
<td>IMPLEMENTATION</td>
<td>42 days</td>
<td>Mon 2/2/09</td>
<td>Tue 3/3/09</td>
</tr>
<tr>
<td>TESTING &amp; EVALUATION</td>
<td>30 days</td>
<td>Fri 3/6/09</td>
<td>Thu 4/6/09</td>
</tr>
<tr>
<td>MODIFICATION</td>
<td>13 days</td>
<td>Mon 4/20/09</td>
<td>Wed 5/13/09</td>
</tr>
<tr>
<td>DOCUMENTATION</td>
<td>65 days</td>
<td>Fri 2/13/08</td>
<td>Thu 5/14/09</td>
</tr>
</tbody>
</table>
1.2 Project Schedule Descriptions

Analysis Phase: This is the foundation of all other phases in the design of the courseware. Data gathering took place at this stage. Pre-development test is conducted to get the response and feedback from the user regarding the effectiveness of having the Mathematics courseware for the students.

Design Phase: At this phase, the storyboard need to be designed based on the information gathered from the school syllabus that is form four secondary school. The outcome of this analysis phase creates blueprint for the instruction. This blueprint is called design document which covers the instructional strategies, content and creative treatment.

Development Phase: This phase uses the output of both the analysis and design phase. During this phase, I develop the instruction, the media to be used in the instruction and any supporting documentation based on the result from the data gathering pre-test results.

Implementation Phase: This phase refers to the actual delivery of the instruction. It should be classroom-based, lab-based, or computer-based. Macromedia Flash action script is a main programming language use to implement the courseware. Other supporting software includes Adobe Photoshop, Adobe illustrator, Sonic Foundry and Microsoft Visio.

Evaluation Phase: The evaluation phase measures how effectively the courseware can accomplished its stated goals. This stage proved that the use of multimedia elements
like graphics, animation did help the elementary school children in learning the concept of Quadratic Function topic.

**Documentation Phase:** This phase took place after all the data needed has been gathered for this project and analyzed.

**1.3 Conclusion**
Mathematics is an important subject but students still have difficulties in studying Mathematics. Therefore, educational design for effective learning and teaching environment is important to facilitate in learning Mathematics. Information Technology in the form of courseware can be used effectively to individualize instruction. The courseware has incorporated interesting and colorful graphics as well as animation to enhance students’ interest on the lesson taught. In addition, this Mathematics courseware follow the syllabus, therefore, parents or students would not have to worry regarding the content itself. The scope of this research is form four students or higher secondary level school students. This courseware adapt the perpetual navigational approach which helps students use the courseware more effectively as they are constantly aware where they are in the program. This courseware uses the CLT method to see the effectiveness of learning the Mathematics subject focus on the topic on Quadratic Function. Before the prototype had been designed, pre-test questionnaires had been asked to the users to get the idea of designing the Cognitive Load Theory based model courseware. The findings of the data gathering helped a lot in terms of designing the courseware. The prototype of this courseware is developed in an interactive environment, therefore students can carry out the exercise given hence they can get the result on the level of their understanding towards the topic. This research conduct tests and evaluations on the courseware prototype based on the student’s participation.
CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

This chapter reviews pertinent literature related to how Cognitive Load Theory based model can be applied in Mathematics courseware. Through an overview of learning, instructional theories and model, an understanding of the underlying theories in the design process can be formulated. This investigation assisted in the development of this Mathematics courseware, designed to create the best practices of instructional design in the implementation of Mathematics courseware for higher secondary school in Malaysia.

2.1 Multimedia Components

Animation

Animation is the art of movement. It is the rapid display of a sequence of images of 2D and 3D artwork or model positions in order to create an illusion of movement. The most common method of presenting animation is as motion picture or video program, although several other forms of presenting animation also exist.

Graphic animation uses non-drawn flat visual graphic material (photographs, newspaper clippings, magazines, etc) which are sometimes manipulated frame-by-frame to create movement. At other times, the graphic remain stationary, while the stop-motion camera is moved to create on-screen action.
Narration

Narration can be used in all school subjects and in all experiences. Narration is a very powerful learning tool. According to Charlotte Manson (2003), perfect attention and absolute recollection is an asset to teacher and nation. She said adults read and forget but her students have the powers of perfect recollection and just application because they have read with attention and concentration and have in every case reproduced what they read in narration.

Graphic

In multimedia computer environment, the first step towards enriching a textual message is to integrate images to supplement the information. Graphical images are used to add emphasis, direct attention, illustrate concepts and provide background content. Graphic design is basically a visual problem solving using text or graphical elements. The aim of graphic design is to create something that is pleasing to the eye and gets attention to the viewer.

Audio

Audio’s main benefit is a channel of information separate from the display. Extensive studies have been done on “Cognitive Dissonance” in relation to televised news. News stories where the audio and video are not closely aligned in content score which in lower in comprehension than stories with a close correlation between visual and aural content (Edwardson & Kent 1992).
2.2 Related Study

Student accessing multimedia courseware are not bound by time and place, whilst also being able to engage with learning activities in an interactive and self-paced manner. Multimedia involves a combination of multiple modes such as text, graphics, animation, audio and video to present information for learners. Multimedia – based learning has increasingly proliferated in education circles, having been shaped by rapid technological advancements. Mathematics courseware titled Quadratic Function, designed for form four students had been used to get some information about the CLT based model.

2.2.1 Strengths and Weaknesses of the Courseware(s)

2.2.1.1 Smart School Courseware

Strengths:

I. The content itself follow the syllabus and the additional content in provided by the Subject Matter Expert (SME). This is shown at Figure 1.0 and Figure 1.2. SMEs are teachers with the Mathematics background (Hai, T.B 2006).
II. The courseware content has many sections such as the learning, activity and exercise section where users have many choices to run the courseware and study them.

III. The use of multimedia elements in the courseware attracted attention from the users such as graphic, animation and sound used in the courseware.

According to Hai, T.B. (2006), the design of the current Mathematics courseware titled *Fungsi Kuadratik* can be considered poor because of a few factors.

**Weaknesses:**

I. The existing courseware did not apply the Cognitive Load Theory, therefore sometime users use the maximum memory load in order to learn the topic(s).

II. The color scheme used is not attractive and suitable for the students, as shown in Figure 1.0, Figure 1.1 and Figure 1.2. Therefore students feel bored while running the courseware.

III. The arrangement of the text and graphic not much different from the text book. The design layout is an important role for the designer to develop the CLT based model courseware.

IV. There are too much text displayed in the slide and can be said as page turner learning tools, for example in Figure 1.0 and Figure 1.1. In addition, Mayer (1998) agreed that learning can be enhanced by displaying the graphic images and voice over concurrently with the text. This important point is not applied by the courseware X at Figure 1.0 where its content is filled by the displayed text only.
Jual nilai x yang memenuhi senarai ketaksamaan kuadratik boleh ditentukan dengan menggunakan kedah lekaran graf seperti langkah berikut:

(i) Tulis ketaksamaan kuadratik dalam bentuk
    \[ f(x) > 0 \text{ atau } f(x) < 0 \text{ atau } f(x) \geq 0 \text{ atau } f(x) \leq 0. \]

(ii) Faktorkan \( f(x) \) dan selekasnya tentukan nilai x bagi \( f(x) = 0 \).

(iii) Lukarkan graf \( f(x) \) dengan nilai x yang telah diperolehi dalam (ii).

(iv) Tentukan jual nilai x yang memuatkan ketaksamaan kuadratik daripada graf.

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**Figure 2.0: Content Screen without CLT**
*(Smart School 2003 Mathematics Courseware)*

**Figure 2.1: Content (2) Screen without CLT**
*(Smart School 2003 Mathematics Courseware)*
Nowadays, multimedia in its different forms penetrates a lot of differences communication environment such as the view of multimedia based on network communication (for instance www) as well as digital stored media (such as CDROM).

2.2.1.2 Online learning
**Strengths:**

I. The content itself is standardized, means that it can be used for the students at higher secondary level school.

II. The design layout support what has been agreed by Moreno & Mayer (1999), the integration of pictures and text when they are placed physically close to each other on the page or screen.

III. The use of multimedia elements in the courseware attracted attention from the users such as graphic, animation and sound used in the courseware.

**Weaknesses:**

I. The above courseware did not showed the accurate value on the graph displayed therefore sometime users use the maximum memory load in order to learn the topic(s).

II. The design layout should be improved more in terms of the tab(s) displayed for example if the users want to skip the section they may do so if there is a choice.
### 2.2.2 Study on Instructional Materials and Pedagogy in Mathematics.

Table 2.0: Existing Study Using Other Types of Instructional Materials and Pedagogy Method for Teaching Mathematics.

<table>
<thead>
<tr>
<th>Researcher(s)</th>
<th>Instructional Materials and Pedagogy</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Idris N. 2010)</td>
<td><strong>Graphing Calculator</strong> is a tool teachers can employ to pull students, students are encourage to participate in classroom discussion, asking for explanations and justification of answers and thus creating a climate to success. Consequently, these calculators may also encourage students to learn Mathematics in a more enjoyable, yet effective way.</td>
</tr>
<tr>
<td><em>A Graphing Calculator - Based Instruction in Learning Mathematics</em></td>
<td></td>
</tr>
<tr>
<td>(Charles A Dana Center 2007)</td>
<td>The implementation of <strong>Mathematics TEKS</strong> (Texas Essential and Knowledge Skill) is developed to help schools timely, efficient and comprehensive manner. TEKS promote students’ active involvement in learning Mathematics.</td>
</tr>
<tr>
<td><em>Mathematics Instructional Materials Analysis: TEKS Implementation</em></td>
<td></td>
</tr>
<tr>
<td>(Kafai Y.B. 1996)</td>
<td>She developed <strong>Game Based Design Project</strong> to teach Mathematics (Fractions) to young students. With the implementation of this project, the theoretical foundation of the pedagogy learning through design, and a review of the research on learning <strong>Logo programming and fractions</strong>.</td>
</tr>
<tr>
<td><em>Minds in Play: Computer Game Design as a context for children’s learning</em></td>
<td></td>
</tr>
</tbody>
</table>
2.3 Cognitive Load Theory Concepts

Cognitive load theory (CLT) is a comprehensive set of evidence-based guidelines for the design and development of instructional materials that utilize the strengths and accommodate the restrictions of human working memory.

Cognitive Load Theory has been designed to provide guidelines intended to assist in the presentation of information in a manner that encourages learner activities that optimize intellectual performance (Sweller & Pass 1998, p. 251). Interactive learning environments respond dynamically to learner’s actions and are associated with active, learner engaged processing of learning materials.

Moreno and Mayer (2003) provided several useful guidelines, which are research based on CLT for learning through courseware. They provided guidelines on how to apply the research and psychology behind the core principles of CLT, extraneous, intrinsic and germane types of cognitive Load.

The base premise of Cognitive Load Theory is that the focus of an instructional module must be instruction itself. Information that is adjunct to the instruction must be designed to minimize cognitive load and enhance working memory. Since the mental resources of working memory can be overloaded, any information that ignores cognitive load may interfere with the process of acquiring knowledge and skills. The principles of CLT had been applied in the design of the instructional courseware and discovered that cognitive load theory provide a sound baseline for the design of effective courseware instruction. In addition, to effectively enhance the courseware instruction, the Graphical User
Interface (GUI) and multimedia formats must be developed in consideration of Cognitive Load principles.

Developmental theories portray changes in mental abilities (cognition), social roles, moral reasoning, and beliefs about the nature of knowledge. Based on Jean Piaget’s theory of development, a child is possibly able to think abstractly about mathematics, but remain limited in concrete thought when reasoning about human correlations.

Sweller (1998) suggested that instructional designer should limit cognitive load by designing instructional materials such as worked examples or goal-free problems. Moreover, CLT has extensive implications for instructional design, more common within most instructional materials. Specifically, it can be said that CLT provides guidelines that help instructional designers to diminish extraneous cognitive load during learning. This theory can be seen between three types of cognitive load:

- **Intrinsic Cognitive Load** – all instruction has an inherent difficulty correlated with the calculation of 2+2, versus solving a differential equation. For instance, mental calculation of 3+3 has lower intrinsic load than solving an advanced algebraic equation, due to a higher number of elements that must be handled concurrently in working memory.

- **Extraneous Cognitive Load** – information is presented to learners and is under control of instructional designers. According to Sweller (1998), in order to describe things, it’s not necessarily through verbal explanations, indeed it can be visually explained, for example audiovisual presentation will usually have lower extraneous
load than a visual-only format, since the audio modality is also being used to convey information to the learner.

- **Germane Cognitive Load** – load assigned to the processing, construction and automation of schemata. For examples, knowledge and skills that are used frequently, such as reading, may be accessed automatically without high levels of conscious effort even though the associated task may be complex.

Figure 2.4: Intrinsic and Extrinsic Cognitive Load

CLT is an instructional model approached from the field of cognitive Science Research. It illustrates learning in terms of an information processing system made up of long term memory, which stores knowledge and skills on a more-or-less permanent basis, and working memory which performs the intellectual tasks associated with learning (Cooper 1998). Instructional designers can manipulate extraneous load to increase learning efficiency and effectiveness (Clerk 2005).

CLT emphasizes various practices that can be applied to the performance improvement. The most crucial of these comprise methodologies for reducing the effects of extraneous Cognitive Load of instructional materials to ensure optimal learning. These effects include Split Attention, Redundancy, and Modality.
1) **Split Attention**

Materials that need users to split their attention between two sources of information causes a higher Cognitive Load on working memory and therefore delay the learning process (Mayer & Moreno 2003).

For instance, the placement of text adjacent to an illustration create less cognitive load to the learner, since less effort is involved in the integration of pictures and text when they are placed physically close to each other on the page or screen (Moreno & Mayer 1999).

![Figure 2.5: Split Attention Effect](image)

2) **Redundancy**

Either textual or graphic source of instructions, offers full intelligibility, then only once source of instruction should be used. In this contexts a single source of instruction returns higher levels of learning than multiple resources, whether having an integrated
format (for instance, text integrated into a graphic) or a dual format (both text and graphic presented in parallel), (Mayer 2001).

![Redundancy Effect Diagram](image)

**Figure 2.6: Redundancy Effect**

3) **Modality**

Based on Cognitive Load Theory, the addition of audio narration to a visual presentation enhances understanding and related problem solving.

![Modality Effect Diagram](image)

**Figure 2.7: Modality Effect**

Mayer (1997) and Sims (1994) showed that learning was enhanced when pictorial and spoken materials were presented concurrently rather than sequentially. Sweller (1991) designed Cognitive Load Theory while studying problem solving. Instead of problem solving, he advocated that the instructional designers should bound Cognitive Load by designing instructional materials like worked-examples or goal-free problems.

Gagne (2003) proposed that learning is like a making process which consumes a hierarchy of skills that raise complexity. There are five categories of learning which are verbal information, intellectual skills, cognitive strategies, Motor Skills and Attitudes. His notions of task analysis and the importance of the correct sequencing of instruction are used by most mathematics teachers when designing their programs.
2.4 Role of Technology in Education - Smart School in Malaysia

In line with vision 2020, which calls for sustained, productivity growth which will be achievable only with a technologically literate, critically thinking work force prepared to participate fully in the 21st century. Malaysia intends to transform its educational system, moving away from memory-based learning designed for the average student to an education that simulates thinking, creativity and caring in all students, caters to individual abilities and learning style and is based on more equitable access (Yaacob, J & Noor, N.M. 2005).

Smart school education programmed is an innovative concept that integrates teaching and learning with Information Technology applications that include computer-based teaching. This programme has been implemented in year 1999. Smart schools aim to develop and produce future generations who are technologically literate.

In traditional learning environment, teachers transfer the knowledge to the learner through the medium of printed materials, particularly text books. There is no technology usage and the practice of asking students collaborative is often lacking. Courseware learning enables students to use the tools in a distance education phase using compact disc as the main medium for all students learning and contact. This type of learning environment has been claimed to promote opportunities for collaborative and explorative learning or engaged learning.

The growth of information and communication technology (ICT) has led to ‘Revolutions in Learning’ as each new technology innovation in education and the application of new methods and instruments in teaching – learning practices.
Teachers need to understand how an ICT based learning conditions, as intended by the smart school education concept, affects the student’s learning. Courseware has been designed to facilitate student’s active, creative and critical engagement with the content can help students to get better understanding towards the contents of the subjects.

In achieving the aim, the incorporation of IT supported learning has been emphasized in the curriculum, pedagogy assessment methods and materials for teaching to ensure the success of the smart school initiative. Mathematics is one of the subjects that falls under the smart school project.

Table 2.1: Comparison between Traditional Environment and SMART Curriculum

<table>
<thead>
<tr>
<th>Traditional Environment of Teaching and Learning</th>
<th>SMART curriculum</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Transform information</td>
<td>• Question for knowledge</td>
</tr>
<tr>
<td>• Memory based learning</td>
<td>• Analytical &amp; Creative thinking</td>
</tr>
<tr>
<td>• Isolated unit of individual classroom</td>
<td>• Student centered-Autonomous Learner active learners</td>
</tr>
<tr>
<td>• Textbooks</td>
<td>• Global context</td>
</tr>
<tr>
<td>• Teacher Oriented</td>
<td>• Integration of technology</td>
</tr>
</tbody>
</table>

Pedagogically, teachers need to re orient themselves as ‘sage to stage’ to ‘guide on side’. Teachers will identify goals, define direction for their students, pilot their progress towards these goals and then step back to allow the students to learn at their own pace. They will give psychological support and encouragement. They will periodically step in to check progress, applaud strengths and efforts, identify
weaknesses and decide what kind of practice the students will need. In short, teachers will be instrumental in creating conditions that will promote self-directed learning which is creative and independent. They need to teach students application strategies to competently and selectively navigate for information. In addition, team effort, group collaboration, flexibility and competency in international languages need to be taught and mastered (Goh, C. & Taib, Y. 2006).

Introducing ICT into all school in Malaysia is a major project, but it represents an investment in the future productivity of Malaysia’s workforce and a down-payment on the country’s future prosperity. All agencies in the educational system and sufficient funds to maintain ICT in the school. Eventually, continuing professional development for teachers, school heads and other educational personnel must be instituted.

<table>
<thead>
<tr>
<th>Researchers</th>
<th>Researches</th>
</tr>
</thead>
</table>
| **Jan, L.P. & Moreno R.**  
(Cognitive Load Theory book, 2010) | • CLT provide instructional designers with guidelines for the design of multimedia learning environments that include verbal representations of information (eg. text, narrated words) and pictorial representations of information (eg. Animation, simulation, photos, video) as well as for the design of web-based learning environments.  
• CLT has been widely used as the theoretical framework for several instructional design areas, such as complex problem-solving environments. Worked-example instruction and multimedia learning. |
• Mayer & Moreno provided several useful guidelines, which are research based on CLT for learning through courseware. They provided guidelines on how to apply the research and psychology behind the core principles of CLT, extraneous, intrinsic and germane types of cognitive Load.

• At the other extreme, information could have high element interactivity such as learning complex mathematics equations or learning the grammar of a second language, or any kind of learning that can be called ‘learning with understanding’. This kind of acquisition requires all elements that interact to be processed concurrently, a situation that might result in a high cognitive load.

• CLT is both theory of cognition and learning and a instructional design model. Students learn better at solving Mathematics problem when they study worked-examples better than they solely engage in hands-on problem solving.

2.5 Managing Cognitive Load in an Interactive Environment

According to the feedback principle (Moreno, R. & Mayer, J. 2007), novice learners learn better with explanatory rather than corrective (simple) feedback because the explanatory feedback is the one capable of providing external instructional guidance instead of missing internal mental structure.
In adaptive environments, as learners attain more experience in the domain, detailed explanations need to be gradually omitted and a relative share of problem-solving practice or exploration increased consistent exposure of learners to guidance messages constructed higher gains in scientific inquiry skills and domain-specific knowledge (Atkinson & Renkl 2007).

A recent application is research sharing that students learn to become better at solving mathematics problem when they study worked-out examples better than when they solely engage in hands-on problem solving (Sweller 1999).

Dispassionate review of the relevant research literatures shows that discovery-based practice is not as effective as guided discovery (Mayer 2004). Kirschner (2006) described worked examples as an instructional design solution for procedural learning. Evidence for learning by studying worked-example is known as worked-example effect and has been found to be useful in many domains such as physics, mathematics or programming (Giller, S. & Barker, P. 2004).

2.6 Cognitive Theories of Learning Mathematics

Categorization can provides a possible set of answers to how learner derives information from the environment (Bruner 1979). In this Mathematics courseware, I have categorized a few sections that are Isi Kandungan (Content), Latihan (Exercise), Aktiviti Pembelajaran (Learning Activity) and Ujian Formatif (Formative Test). For Learning Activity category, students learn on the content of the Quadratic Function. Latihan (Exercise) section provides sets of questions to the students. Bruner (1979) listed 2 stages of particular disciplines to the students. For examples:
• **Iconic** – students learn through models and pictures. In this mathematics courseware developed for this project, each section has been provided with the colorful graphic images to make the courseware interesting.

• **Enactive** – students learn through actions on objects. In this mathematics courseware, actions referred to the buttons.

### 2.6.1 Cognitive Load Theory Proposed Design

After reviewed the existing courseware without the Cognitive Load Theory method application, the proposed designed had been draft in storyboard format to get the idea about CLT method.

- CLT courseware should consider the working memory load to the user. This is what Mayer (1998) agreed that learning can be enhanced by displaying the graphic images and voice over concurrently with the text. This is shown in Figure 2.4 below.

![Figure 2.8: CLT courseware proposed design I](image-url)
• Mayer (1997) stated in his theory that the screen itself should be designed by the designer either with pictorial or text in order to make the courseware understandable. The placement of text adjacent to an illustration creates less cognitive load to the learner, since less effort is involved in the integration of pictures and text when they are placed physically close to each other on the page or screen (Moreno & Mayer 1999). The proposed design as shown in Figure 2.5.

![Courseware Title](image)

**Figure 2.9: CLT courseware proposed design II**

• Sweller (1998) suggested that instructional designer should limit cognitive load by designing instructional materials such as worked examples or goal-free problems. By providing the hint to the students, mental calculation of the activity’s given has lower intrinsic load than solving an advanced equation, due to a higher number of elements that must be handled concurrently in working memory. Example of this idea has been design similar in Figure 2.6 below.
2.7 Conclusion

Displaying the worked examples, step-by-step instruction can reduce the cognitive load (Sweller 2005). In addition, Mayer (1997) agreed that learning can be enhanced by displaying the graphic images and voice over concurrently with the text. Malaysia in trends to transform its educational system moving away from memory-based learning designed for the average student from education that simulates thinking, creativity in all students, caters in individual abilities and learning style and is based on more equitable access. The growth of information and Communication Technology (ICT) has led to ‘Revolutions in Learning’ as each new technology innovation in education and instruments in teaching-learning practices. Evidence for learning by studying worked-example is applied in physics, mathematics or programming subjects (Giller, S. & Barker, P. 2004).
CHAPTER 3
RESEARCH METHODOLOGY

3.0 Introduction

The culmination of the research in the previous chapter led to use of Cognitive Load Theory based model for the designing of the courseware. The approaches applied are based on the literature reviews and analysis in order to achieve the research objectives. The literature review provides good information and direction to determine the suitable methods and approaches for the research. Credentials limitation and constraint that may affect the development are also detailed out in this chapter.

For this courseware development, methods that have been conducted for the whole project were questionnaires and interviews. All these methods had been conducted before the completion of the project and after the development phase had been completed. During the literature review, comparison analysis technique has been used for data gathering. Likert Scale 5 is used as a Questionnaires technique, whilst Think-aloud is used as the interview technique. A few sources from journals, books or electronic media were analyzed and evaluated followed by evaluation on questionnaires and interviews.

Setting – the field studies have been conducted in a big urban side school with about 200 over form four students. The school has a few computers occupied at the Computer Labs. The studies were carried out over eight to twelve months. On average there were thirty-five students in each class. A questionnaire that is filled by each student was held in the Computer Lab after the school session finished.
Scope of this research - teachers and higher secondary school students from four different schools in Klang Valley (Sekolah Menengah Damansara Damai, Selangor, Sekolah Menengah Taman Desa Rawang) and Penang area (Sekolah Menengah Alma, Bukit Mertajam). There are about 6 teachers and 30 students involved in the testing stage.

3.1 Data Gathering

To get the evidence on the research and to ensure that the information gather reliable and meet the user’s requirements, two types of data gathering techniques involved in this research, which are pre- test and post-test.

I. Pre-development Test

Before the development started, a few questions need to be analyzed in order to improve the development of the Quadratic Function design of the courseware. The result of the findings shows the percentage of the student’s score based on the exercise given from the courseware. The result can be viewed in chapter five.

II. Post-development Test

After review all the outputs, the development of the Cognitive Load courseware titled Quadratic Function has been designed. Post-test questions have been analyzed and the positive response can be viewed from the table 5.0 in chapter 5.
This shown that the system which practiced the CLT method better that the system without the CLT method. Moreover, design can be considered as one of the good element to integrate with the CLT method.

Table 3.0: Number of respondents involved in the research

<table>
<thead>
<tr>
<th>Name of School</th>
<th>Number of Teachers</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sek. Men. Damansara Damai Sungai Buloh</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Sek. Men. Taman Desa Rawang</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Sek. Men. Alma Bukit Mertajam</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td><strong>TOTAL RESPONDENTS</strong></td>
<td><strong>6</strong></td>
<td><strong>30</strong></td>
</tr>
</tbody>
</table>

3.2 User’s Requirements

- **Questionnaires**

Rating scale has been used as the questionnaires technique. Responses from the teachers and students were rated using **Likert 5** scale which ranges as follows:

1- **Strongly Agree**

2- **Agree**

3- **Fair**

4- **Do not Agree**

5- **Strongly Disagree**

Questionnaires are very cost effective when compared to face-to-face interviews. This is especially true for studies comprising large sample sizes and large geographic areas. Written questionnaires become even more cost effective as the number of research questions increases. Questionnaires are simple to analyze. Data entry and tabulation for nearly all surveys can be easily done with many computer software packages.
Questionnaires are well-known to most people. Nearly everyone has had some experience completing questionnaires and they generally do not make people apprehensive. Questionnaires diminish bias. There is uniform question presentation and no middle-man bias. The researcher's own opinions will not influence the respondent to answer questions in a certain manner. There are no verbal or visual clues to influence the respondent.

Questionnaires are less intrusive than telephone or face-to-face surveys. When a respondent obtains a questionnaire in the mail, he is free to complete the questionnaire on his own time-table. Unlike other research methods, the respondent is not interrupted by the research instrument.

In order to obtain the users’ requirements, these questionnaires had been distributed to the respondents that are teachers and students because they are the person that using the courseware for this testing. There are 15 questions had been distributed among the thirty secondary students and six teachers.

Five questions had been distributed for the first cycle of development phase (Pre-Development) and ten questions had been distributed after the design of the prototype completed (Post-Development). All the results had been evaluated and analyzed.

- **Interviews**

Interview is better in asking the respondents a few questions about the prototype. One of the techniques I have conducted by interview was **think-aloud** technique. I have
asked the interviewees to describe their opinion about the system once they tested it. The interview takes place before and after the final prototype had been completed.

The interviews have been conducted at three different locations. There are at Sekolah Menengah Damansara Damai, Selangor, Sekolah Menengah Taman Desa Rawang and Sekolah Menengah Alma, Bukit Mertajam, Penang. Six teachers were interviewed for this project. The questions asked can be referred at the appendix C. The feedback of this interviewed will be explained in chapter 5.

3.3 Prototype

In software development design, there are various type of design methodologies that applicable, such as SDLC, OOAD, Waterfall, RUP and many more. These methodologies are a framework that is used to structure, plan and control the process of developing an information system. It is intended to provide a define guidelines, so that the implementation of a system will be consistent and coherent manner.

A prototype is a rudimentary working model of a product or information system, usually built for demonstration purposes or as part of the development process. A prototype has been developed to get the feedback from the users. This feedback was really important in order to give the improvised version of the courseware with the best quality. For the development of the CLT courseware, the methodology that is used is prototyping system life cycle. Prototyping can be described as a process of building a model of a system.
The prototype system is built with the intention to explore some important feature of the system requirements and it is not intended to be a final working system (Simon et al. 2006). The prototype of the courseware has been tested by six teachers and thirty students from Sekolah Menengah Damansara Damai, Sungai Buloh and Sekolah Menengah Taman Desa Rawang, Selangor.

3.3.1 Prototype Evaluation

The prototype evaluation phase concerns about analyzing and validating the results from the test procedure with objectives stated earlier at the beginning of the activity. In this phase, all comments and inputs from user are necessary and if feedbacks are not inline with the objectives, changes to the prototype of the courseware will be made. The last three phases will be repeated until the objectives of the prototyping activity are met.

Initial Analysis phase – This phase involves the understanding and focusing on the preliminary target for the courseware development. The initial analysis is very crucial in order to understand the business case why the project should be attempt. At this stage,
the researcher has analyzed students’ requirements and opportunities to develop the Mathematics courseware using CLT method.

**Define Prototype Objectives** – The objectives of any prototyping activities must be established in the beginning of the project. Although the prototyping activities usually involved many iterations, and each iteration requires modification to the system, but with the clear objectives, the progress of a project will not be misleading.

**Specify Prototype** – This phase involves describing the system concept, specify all system interfaces and specification. The main product of this phase is the functional and functional requirement specification of the Mathematics courseware.

**Construct Prototype** – This phase focuses on the development of the prototype system consists of designing architecture, details model of the courseware and user interface of the courseware. The construction of the prototype system also involves rapid development tool such as Flash script, C++ and Java skills.

**Evaluate Prototype** – This phase concerns about analyzing and validating the results from the test procedure with the objectives stated earlier at the beginning of the activity. In this phase, all comments and inputs from user are necessary and if the feedbacks are not inline with the objectives, changes to the prototype will be made. The last three phases will be repeated until the objectives of the prototyping activity are met.
3.4 Testing

The hardware and software requirements for this courseware are not too high. In order to complete the whole section of the courseware, users need to spend about 60 to 80 minutes.

About thirty students and six teachers were involved during the testing phase. Each of them had the chance to test each section and most of them really like to see the colorful graphics and animated problem solution. The activities provided by the courseware also follow the syllabus and level of their understanding.

3.4.1 Test Plan for the CLT Based Model Courseware

3.4.1.1 Terminology

AT: Acceptance Test

Frame: One module of instructional materials in one learning outcome (LO)

IR: Incident Report

LAT: Laboratory Acceptance Test

LO: Learning Outcome. One launchable group of instructional materials comprising one learning outcome can also be referred to as one lesson.

TLM: Teaching and Learning Materials

3.4.2 Objectives

The Factory Acceptance Test objectives are to focus on the test processes and the overall procedures of testing.
The test approach has several stages,

i) Internal Testing: Unit and System Tests

ii) Courseware Appreciation

iii) Acceptance Testing: AT Test and AT Retest

**Figure 3.1: Testing Approach Stages**

### 3.4.3 Internal Testing

The approach adopted in internal testing a courseware is to use the approved storyboard as the baseline together with any addendums generated during the production and storyboard reviews. Addendum is a record for any changes on the storyboard caused by factual errors and to simplify the complexity of the flowchart. Internal testing comprises of Unit and System Tests.

### 3.4.4 Unit and System Tests

A Unit Test is carried out at the frame level whereas the System Test will test the courseware at the LO level, i.e. integration of several frames forming a courseware or LO (which is the smallest launch-able unit).
Unit and System Tests are carried out to check conformance with approved storyboard, addendum and courseware convention. Errors reported from Unit and System Tests are compiled into Incident Report Form and distributed to appropriate department for correction.

Correction to the courseware normally been completed based on the internal incident report. Retest is then performed on the courseware guided by the report. New errors can also be raised and reported during the retest stage. Retest will be performed until all the errors are fixed. After all the errors are fixed and closed, the courseware is ready for Courseware Appreciation.

3.4.5 Courseware Appreciation

Courseware Appreciation is conducted for the purpose of getting the content of the courseware reviewed by users that are teachers and students. Any suggestions on the
content and factual error caused by the storyboard been reported and compiled into Courseware Review Form and Addendum Form as Courseware Appreciation result. Modification to the courseware based on the Courseware Appreciation result. Retest is then performed on the courseware. Then teachers verified the result. New suggestion(s) are also being raised and reported during the retest stage. Retest been performed after all the suggestions had been fixed and corrected. All the suggestions need to be fixed and closed. After all the suggestions are fixed and closed, the courseware is ready for the users. The process of Courseware Appreciation is shown as below:

5.4.6 AT Testing:
The processes are as follows:

AT Test Process:
The test is carried out based on the addendum, courseware convention and Test Procedure Form. Addendum on factual errors and flowchart simplification, reported
from Courseware Appreciation been part of test document as it has change the storyboard content. Functionality element that did not match with courseware convention is not recorded into the addendum because the courseware convention was the guideline for the test. Test outcome had been recorded in Test Procedure Form. Errors and suggestions was recorded in Incident Report (IR) Form. Any suggestion raised had been discussed with selected teachers (Mrs. Zuraime Ismail from Sekolah Menengah Alma Bukit Mertajam, Penang) or Graphic Designer (Mrs. Latifiyana Yahya from Digital Technologies Sdn. Bhd. Bukit Damansara, Kuala Lumpur).

**AT Retest Process:**

Modification to the courseware will be done based on the IRs. Retests are then carried out based on the IRs and Test Procedure Form.

1. New IR can be raised by the tester (teachers) during retest stage
2. For AT, there were only 3 cycles involved; Test, Retest 1 and Retest 2.
3. The courseware is considered accepted if the Incident Reports are free from errors.
Figure 3.3: The Retest Process
3.4.7 Test Version
The testing has been conducted in Standalone Version.

Standalone Version
The courseware has been launched in unguided mode. The launching and exiting has been conducted based on the Test Procedure Form.

Test Focus
The test focuses on:

- Functionality within each frame, navigation between frames, scores and conventions.
- Impact on the Cognitive Load for the users.

3.4.8 Functionality within each frame and conventions
The functionality within each frame and conventions of an LO has been tested.

Navigation between frames
In standalone version, a user will only be allowed to navigate between frames within the module, depending on the test performance. A student will operate the courseware in this mode.
3.4.9 Roles and Responsibilities

Test Resources: Resources for internal testing:

- **Unit and System Testing: Six teachers and thirty students as Tester.**

  The testers look at the contents, functionality, voice over, graphic and animation, and allocating the modification to be done as soon as possible.

  *Courseware Appreciation: Six teachers as Testers*

  The testers look at the content for the improvement and suggestions for the modification of the courseware.

3.4.10 Resources for AT

During the AT, students performed the testing of the courseware witnessed by the teachers from respective schools. The table below illustrates the roles, numbers of representatives and the responsibility of those involved.
Table 3.2: Roles, numbers of representatives and the responsibility of those involved.

<table>
<thead>
<tr>
<th>Role</th>
<th>Number (Maximum Requirement)</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality Inspection</td>
<td>1</td>
<td>Inspection for quality records for coursewares that had passed the internal test which undergo for AT testing</td>
</tr>
<tr>
<td>Developer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Configuration Management</td>
<td>1</td>
<td>Inspection for system configuration on workstations involved in testing</td>
</tr>
<tr>
<td>Teachers and Students</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tester</td>
<td>3</td>
<td>Evaluating courseware content based on storyboard, performing the test based on AT Test Procedure and preparing the report</td>
</tr>
<tr>
<td>Teachers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Witness</td>
<td>3</td>
<td>Witnessing the test</td>
</tr>
<tr>
<td>Developer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observer</td>
<td>3</td>
<td>Observing the test and the content of the courseware</td>
</tr>
</tbody>
</table>

3.4.11 Test Environment

Test Location: The AT has been carried out at:

Sekolah Menengah Damansara Damai, Sungai Buloh, 47830 Selangor.

Sekolah Menengah Taman Desa 48000 Rawang Selangor.
Sekolah Menengah Alma
Bukit Mertajam
13700 Penang.
Testing Time: 9.30 am to 5.30 pm
(Monday to Friday)

3.4.12 System Configuration

**Hardware:**
- 10 units PC Compaq Deskpro EP Series
- Pentium III 550MHz
- 128MB RAM
- 10 GB Hard Disk
- 14” SVGA Colour Monitor

**Software:**
- Windows XP
- Internet Explorer 5
- Microsoft Outlook Express 5
- Microsoft Windows Media Player 6.01
- MS Office 2003 Professional
- Norton AntiVirus 2000
- Adobe Photoshop CS
- Adobe Premier pro CS3
- Adobe Illustrator CS
- Macromedia Flash Player MX
- SoundForge 6.0
- QuickTime 4 For Windows XP
3.4.13 Test Schedule

The courseware followed the steps described below;

i) Test the stand-alone version of the same LO for its launching and exiting only, as its functionality, navigation, content and scoring is the same with the unguided mode.

3.4.14 Courseware Appreciation

For the first cycle testing, acceptance was based on the performance of the courseware itself and free of factual error. For the second and subsequent testing, namely for retest, acceptance criteria will be based on test reports and addendum documents. The accepted courseware is ready for AT.

Acceptance Test

The acceptance criteria was based on the severity level of each report.

Incident Report:

i. The Incident Report can be raised by the testers (teachers and students), while tester recorded it in Incident Report Form and Test Procedure Form.

ii. The testers determined the severity level of the Incident Report. (Severity 1, 2, 3 or 4)

iii. The severity level of the IR will be determined during the testing.

The Severity Level:

The severity level is divided into 5 levels:

- Level 1 – Critical
  
  Application error that is the test cannot proceed.
• Level 2 – Functional

  Functional error for example mismatch between storyboard and courseware.

• Level 3 – Factual

  Content error for example incorrect concept of CLT or storyboard

• Level 4 – Suggestion

  Feedback for enhancements

The testing is considered complete if the Incident Reports are freed of severity level one, two and three incident error. The courseware will be accepted. For the severity level four, the modification will take place after level one, two and three of severity are rectified for every test cycle.

3.4.15 Test Deliverables

Documents:

i. Pre AT

  • Unit Test Result;
  • Courseware Appreciation Result;
  • Approved Storyboard;
  • System Structure Test Summary;
  • Addendum from unit test and Courseware Review;
  • Courseware Convention.
3.5 Evaluation

There are two types of evaluation methods conducted throughout the development of this Mathematics courseware. Firstly, the System Evaluation and secondly the User Evaluation.

- **System evaluation** took place before the delivery of the final prototype to the users (students and teachers). Some criteria have been evaluated based on the technical view such as the navigation parts. The system should not have any technical error before the courseware is submitted to the users.

- **User Evaluation** took place at the users’ place whereby a few forms were filled by them. The forms are called Test procedure form, Content Rework Readiness and Addendum as attached in the appendix section.

I. **Test procedure form** is the form filled by the tester to indicate that the courseware has been tested based on the name, date and location took place. In addition, tester will follow the test description, the steps using the courseware from the beginning of using the Compact Disc until the end. If there is any functional error, they will comment the errors on the provided form.

II. **Content rework readiness** is used after the testing took place. After the tester comment on the functional or content error(s), the errors should be fixed before the deadline. Moreover the content should be corrected too. Therefore, the details about the developer’s name, venue, date completion should be stated clearly.
III. **Addendum form** is the form where the testing results and comments will be given to the developer. All the correction raised by the users will be corrected and amend based on the timeline stated.

### 3.6 Conclusion

The information collected from the participants’ responses in this study yielded a consensus from experts for best practices of the courseware development. There are three schools involved in this project for the testing purposes. The schools are Sekolah Menengah Damansara Damai, Petaling Jaya, Sekolah Menengah Taman Desa, Rawang and Sekolah Menengah Alma, Bukit Mertajam. Two types of data gathering techniques involved in this research, which are pre-test and post-test. Rating scale has been used as the questionnaires technique. Responses from the teachers and students were rated using Likert 5 scale and the feedback received from the respondents enabled me to develop the CLT based model courseware. The prototype evaluation phase concerns about analyzing and validating the results from the test procedure. The responses were compiled, organized, analyzed and explained in details in chapter five. After feedback was received from the respondents through the interviews and questionnaires, it can be concluded that most of them gave the positive response towards the used of Cognitive Load Theory based model in this courseware. The positive responses meant in terms of the effectiveness, interface design, interactivity sections and the application on the concept cognitive load. Some of the respondents commented and suggested on the courseware itself so that the improvement can be made in future.
CHAPTER 4

SYSTEM DESIGN AND IMPLEMENTATION

4.0 Introduction

I proposed this Mathematics courseware based on the assumption that human use separate systems for processing pictorial and verbal material (dual-channel assumption), each channel is limited in the amount of material that can be processed at one time and meaningful learning involve cognitive processing including building connections between pictorial and verbal representations.

4.1 System Navigation Structure

Design of the navigation structure for this Mathematics courseware is shown in Figure 4.0. The flow for this courseware is non-linear where user can navigate to any screen or sections. When the students launch the courseware, the Montage screen is displayed, followed by the Main Menu screen. At the Main Menu screen, there are list of sections where the students can choose to navigate. The standardization on the navigation buttons plays an important role in this courseware. There are Exit button and Home button displayed whereby user can navigate back to the Main Menu.
4.2 System Design

According to Head (1999), “an interface is the visible piece of a system that a user sees or hears or touches” (p. 4); therefore, interface design is the design of these components. Allen (2003) stated when it comes to interface design, specifically a learner interface, it must be a facilitator not a distraction or complication to the learning. According to Allen (2003), the elements of an effective learner-interface design include (a) reducing cognitive load, (b) facilitating success, and (c) supporting features.
Instructional designers and developers of e-learning must look beyond traditional interface design and usability an e-learning course must also consider the facilitation of the learning process (Feldstein 2002). If learners do experience errors, and have to think about the interface in order to navigate appropriately, and are expending working memory and energy trying to negotiate the course. It is likely learners will not learn what they were supposed to learn, they may not complete the interaction, and they might leave the course.

Figure 4.1: Montage Screen

The montage screen display at the beginning part of the chapters comprised of the multimedia elements such as animations, colorful graphics, text and sound. User has the choice whether they want to skip this page or not. Montage screen play the role to attract attention from the user. The good impact of the montage will make the users feel more interested in using the courseware.
The above Figure 4.2 acts as the separator to indicate that this screen is at the exercise (Latihan) section. In this screen, students will start to do the activities regarding the particular chapter and they may know the level of their knowledge on the topic. Moreover, after completing the whole questions, students may get their answers on the same screen.

According to Elsenheimer (2003), interaction is one of the key elements of engagement within an e-learning course that increases completion rates and enables participants to achieve learning outcomes. He described several levels; the lowest level of interaction as linear navigation going from page to page which requires no real thinking or engagement on the learners’ part. The highest level of interaction that Elsenheimer (2003) explained was questions forcing a learner to think.

However, the terms interactivity and interaction are controversial within the literature. Most of the research on interactivity use these terms interchangeably, however Wagner (1994) makes a distinction by linking interactivity with the delivery modality or
technology and interaction as instructional. Therefore, according to Wagner, an instructional interaction does not necessarily require system interactivity.

![Main Menu Screen](image)

**Figure 4.3: Main Menu Screen**

The above screen is the Main screen for this module titled Quadratic Function. From the Main page students may interact with the sub topics to navigate to the selected page. For this particular courseware on the topic of Quadratic Function, there are divided into four. User can click any tab they wish and need not necessarily follow the sequence.

**Aktiviti Pembelajaran (Learning Activity)** – At this section, students can have a look at some of the exercises given in order to test their understanding towards the specified topic. No marks will be given in this section. There are a few sets of questions displayed in each screen.

**Isi Kandungan (content)** – *Isi kandungan* basically is the section to give the information about the topic. It will explain the topic by providing the examples such as some hints on the exercises. The narration concurrently works with the displayed text.
Some of the formula given shows the details on the steps of the example. This is where the Cognitive Load theory is applied whereby it helps students reduce their working memory in memorizing the formula.

**Ujian Formative (Formative Test)** – This section is similar to quiz section whereby students are given sets of questions and marks will be given at the end of the section. Students can view their score at the Score Page. In addition they can view the answers by clicking on the question number too.

4.3 Comparison between existing courseware and this Mathematics courseware

There are a lots of Mathematics courseware in the market. Even though there are so many coursewares, not all of them follow the correct concept or give the positive impact to the users. This is due to the answer given by the developer. One of the researches that can be done here is on the Cognitive Load Theory perspective. After review some of them, comparison have been made on the weaknesses of the courseware.

As Mayer (1997) stated in his theory that the screen itself should be designed by the designer either with pictorial or text in order to make the courseware understandable. The better version has been displayed below the Courseware X.
Figure 4.4: *Isi Kandungan* comparison Screen

Figure 4.4 show the different between two coursewares.

- Courseware X did not meet the point proposed by Mayer since there are none of the graphic used on that screen. Moreover, it seems that not much difference with the text book. Students need to visualize the concept based on their own understanding. Mayer (1997) agreed that learning can be enhanced by
displaying the graphic images and voice over concurrently with the text. Nevertheless, the courseware which follow the CLT meet what Mayer required.

- The first screen (CLT based Model) shows that the graph displays on the right side of the screen makes the user easy to visualize and minimize their working memory. Sweller (2002) advocated that instructional designers should bound Cognitive Load by designing instructional materials like worked-examples or goal-free problems.

Figure 4.5: *Isi Kandungan II* comparison Screen (Both screens have audio)
As in Figure 4.5, the second image (non-CLT based Model) shows that the courseware did not show the clear graph of the Quadratic Function compared to the first image. The second courseware not much differ with the text book, it just pop up the text without any animation or clear explanation.

Based on the extraneous Cognitive Load, audio visual presentation will usually have lower extraneous load than visual-only format. For courseware X, there is a graphic displayed but not really clear compared to the first courseware (CLT based Model) where by tracing the graph on the graph paper, the students can see the graph clearly and the value displayed are more accurate compared to the second courseware. As described by Merriënboer, V. and Sweller (2005) “cognitive load theory (CLT) uses interactions between information structures and knowledge of human cognition to determine instructional design” (p. 147). In order to design interactions that promote learning instructional designers need to understand the cognitive processes a learner is experiencing during the learning process. Hooper and Hannafin (1991) suggested not only to understand these processes but also to base instructional strategies on the cognitive processes our learners employ in order to learn. Kennedy (2004) also discussed cognitive processes but refers to them as cognitive strategies. “Cognitive strategies are the internal mental processes, operations and procedures that students engage in to acquire, integrate, organize, and retain new information”. Kennedy (2004, p.58) defined the term cognitive interactivity as “a continuous, dynamic relationship between instructional events and students’ cognitive processes that are mediated by their behavioral processes”.

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Worked examples are another instructional strategy specific to the facilitation of integrating new information with existing knowledge in order to improve retrieval. According to Merriënboer, V. and Sweller (2005, p. 151), worked examples “reduce extraneous cognitive load caused by weak-method problem-solving; focus learner’s attention on problem states and useful solution steps”. The concept behind worked examples is to reduce extraneous cognitive load by presenting a systematic process of solving a problem that a learner can review and reflect upon. Merriënboer, V. and
Sweller (2005) also discussed completion examples. The concept of completion examples brings worked examples one step closer to problem-solving by continuing to decrease the cognitive load through stepping a learner through most of the problem but then increasing germane cognitive load by requesting that the learner completes the problem on their own. The example of this point can be viewed in Figure 4.6: CLT based-model courseware.

- The first screen of Figure 4.6, there are hints provided to the uses and also user(s) are provided with the virtual calculator to ease their calculation. Another instructional strategy that facilitates integration is a conversational style of narration and storytelling within the context of real-life scenarios (Allen & Clark 2003). These instructional strategies also activate prior knowledge and facilitate the integration of new information into the appropriate schema. Both storytelling and a conversational style are cognitively engaging and they give the learner the context to build upon and relate back to when the learner attempts to apply the newly acquired knowledge once they are back on the job. According to Clark (2006), conversational style can be used effectively by presenting information more personally by speaking directly to the learner through the use of the first and second person.

- According to Allen (2003), storytelling within the context of real-life scenarios places new information in context, creates a memorable structure, increases credibility, engages learners, allows learners to build on their current knowledge and experience, improves retrieval, and improves transfer of learning. Although practice is not accomplished through all interactivity, interactivity within the courseware
environment is necessary for practice. As Schwier and Misanchuk (1993) stated, “Practice is a larger construct which subsumes a much wider range of activity than just interaction” (p. 180). Schwier and Misanchuk recommended 10 principles for practice within a learning environment based on instructional theory.

Vary the practice exercises. In this Mathematics courseware, the development of the selection of exercises styles will give the students practice in the activities based on the topics given. For instance drag and drop, fill in the blanks and click on the answers provided.

Increase the complexity and difficulty level of practice as a learner gains new knowledge and skills throughout the course. The exercises given range from the beginners level up to the advance level.

Begin practice with hints, cues, and tips. Then as the learner progresses through the course begin fading this type of support. By providing these hints and cues will make explanation of the topic clearer and understandable.

Start with practice early and often and gradually increase the time in-between practice. In this courseware, student can start to do the practice section called Diagnostic Check at the early stage. Then, they will know the level of their understanding of the subject.

Although a summary where presented information may not be interactive, it is cognitively engaging and therefore promotes recall. This point is applied the
courseware. The summary section helps the students to remember what they had learned. *Feedback for all practice should be provided whether the correct or incorrect answer is supplied.* The feedback should also provide guidance.

*Integrate strategies that provide organization to the presented information, for example, “mnemonic devices, concept maps, epitomes, analogies, and outlines”* (p. 183).

*Require learners to not only apply new information presented but also to “discover and derive new relationships in information”* (p. 183).

Merriënboer, V. (1997) suggested “variability of practice,” which according to the author will “encourage learners to develop cognitive schemata, because it increases the chances that similar features can be identified and that relevant features can be distinguished from irrelevant ones” (p. 188).

The more experience a learner has with a concept or a skill, the easier they are willing to retrieve information from long-term memory without involving their working memory, making it easier for them to incorporate the new information. Then there are those that are considered experts where automaticity is possible. Automaticity as explained by Clark (2003), where a learner does not need to engage working memory at all to retrieve information related to a task (cognitive or behavioral) that has been performed many times. Less experienced learners might resist with new concepts and skills because they need to use their working memory to practice the new concepts or skills and to retrieve the existing knowledge. Of course, how much they need to involve
their working memory is reliant on what their understanding is with the content and the delivery modality.

4.4 System Implementation

Design of efficient interactive learning environment should take into account the main features and limitations of cognitive architecture. Cognitive Load methods can be used for enhancing or improving the instructional efficiency of interactive learning materials. Although traditional classroom can be considered as interactive learning, it can be said that computer based or courseware act as an interactive learning environments.

4.4.1 Interactivity

In this courseware, it allows user to control the courseware. In other words, it can be considered as a higher level interactive environment. For instance, user can interact while the system will provide the feedback. There are four types of level of interactivity:

4.4.2 A feedback level.

The lowest level of interactivity is associated with providing a predefined feedback on specific learners’ action (solution steps, questions, local search queries, answers, next step hints, etc). The feedback could be immediate or delayed, simple, corrective (yes-no, correct-incorrect) or extended, explanatory (example, principle-based explanations, word references, glossaries, help), with or without learner control (examples: an automatic feedback or feedback on demand). Different combinations of these features would determine different sub-levels of interactivity from simple automatic feedback to extended on-demand feedback (Atkinson & Renki 2007).
4.4.3 A manipulation level

Figure 4.7: Sample of click-and-drag technique Screen. (CLT based Model screen)

It involves real-time online change or transformation of information in response to learners’ action. In contrast to the fixed, ready-made responses at the previous level, the manipulation level provides flexible, variable responses, although not tailored to the learner previous behavior. Usually this level of interactivity allows different degree of learner control (such as moving objects by using click-and-drag technique, rotating an object, manipulating a simulation by entering specific values for input parameters, selecting answer options for web search queries, etc) although it could also be fully system controlled, for instance, worked-cut simulations or dynamic visualizations (animation, rotation, etc) that demonstrate the process to the learner as response to her or his actions. This can be seen in Figure 4.6.
4.4.4 An Adaptation Level

It involves responses that are tailored to the learners’ previous behavior, even though they are drawn from a fixed set of options. Adaptive interactive courseware environments dynamically tailor the selection of learning tasks, instructional procedure and formats based on the information about learner actions and online behavior. It can be either system controlled or learner controlled.

4.4.5 The CLT concept in learning the content of *Fungsi Kuadratik*

**Table 4.1: Steps on CLT method application –*Isi Kandungan 1 screen.***

**STEP 0**
The introduction on the problem solving exercise. Student need to understand what kind of question.

**STEP 1**
From the question given, the first step is to build a table and filled in the related numbers required.
STEP 2
Plotting the point in order to draw a correct graph.

STEP 3
Draw the graph.

STEP 4
System highlight with red line and blue line to differentiate the X-axes and Y-axes.
STEP 5
Plotting the point in order to draw a correct graph.

STEP 6
Last step, it shows the result and user can view the answer on the graph as well.
### Table 4.2: Design Principles on the CLT courseware proposed by Mayer and Moreno (2002).

<table>
<thead>
<tr>
<th>Principles</th>
<th>Quadratic Function Courseware</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Multiple Representation Principle</td>
<td>YES</td>
</tr>
<tr>
<td><img src="image_url" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td>2 Contiguity Principle</td>
<td>YES</td>
</tr>
<tr>
<td><img src="image_url" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td>3 Split Attention principle</td>
<td>YES</td>
</tr>
<tr>
<td><img src="image_url" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td>4 Coherence Principle</td>
<td>YES</td>
</tr>
<tr>
<td><img src="image_url" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td>5 Modality Principle</td>
<td>YES</td>
</tr>
<tr>
<td><img src="image_url" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td>6 Personalization Principle</td>
<td>YES</td>
</tr>
<tr>
<td><img src="image_url" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td>7 Redundancy Principle</td>
<td>YES</td>
</tr>
<tr>
<td><img src="image_url" alt="Image" /></td>
<td></td>
</tr>
</tbody>
</table>

### 4.5 Conclusion

The design of the courseware will give the major impact in terms of the working memory load to the users. Designing this Mathematics courseware based on the Cognitive Load Theory was proposed by a few researchers such as Sweller, Pass, Bruner and others. Besides giving positive impact to the working memory, it may attract attention from the users by displaying the right graphic images, text, animation
and other multimedia elements. Even though interface design is not the main research here but as Alen said, design can act as the facilitator not a distraction of the courseware. This Mathematics courseware has five categories. There are Aktiviti Pembelajaran (learning activity), Isi Kandungan (content), Latihan (exercise), Ujian Formatif (formative test).

Mayer (1997) agreed that learning can be enhanced by displaying the graphic images and voice over concurrently with the text. Moreover, the instructional designers should bound Cognitive Load by designing instructional materials like worked-examples are another instructional strategy specific to the facilitation of integrating new information with existing knowledge in order to improve retrieval. Cognitive Load methods can be used for improving the instructional efficiency of interactive learning materials.
5.0 Introduction

System evaluation and discussion for this Mathematics Courseware was held after the development stage was completed. Initially, the prototype had been tested to find any existing bugs in terms of functional and technical errors. Later, the usability of the prototype was conducted among users who are students and teachers.

5.1 Testing and Evaluation

After the development phase has been completed, the evaluation stage took place to make sure this courseware meet the objective, whether this courseware can improve their mathematics skill based on the cognitive load theory method.

Initially, after the mathematics courseware on Quadratic Function was launched, the loading part took only about a few second in order to link to the main menu page. This courseware can be considered easy to use whereby it is just a standalone system and need not have any internet connection. Students and teachers can use this courseware anytime at any place.

After evaluating and analyzing the questionnaires and interviews, it shows that this mathematics courseware met the pedagogy criteria. Teachers of all schools agreed that the syllabus and instructional method which is using the courseware as additional teaching method helped the students to gain a better understanding of the concept explained by the courseware. Moreover the system gave the correct output for instance at the score page. In terms of the navigation part, the flow of this courseware is non-
linear, therefore users can navigate throughout the module based on their own preferences. No bugs and technical error found by the users when they used this courseware.

5.2 Results and Discussions

5.2.1 Student’s Performance

Table 5.0 shows the Mean of the student’s score before and after the CLT method being applied in the courseware and the increase of the score from 30 students.

Table 5.0: Effectiveness of the System based on the CLT Courseware.

<table>
<thead>
<tr>
<th>Users</th>
<th>Pre-Test Score (10 questions)</th>
<th>Post-Test Score (10 questions)</th>
<th>Increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>5</td>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>P2</td>
<td>6</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>P3</td>
<td>5</td>
<td>9</td>
<td>40</td>
</tr>
<tr>
<td>P4</td>
<td>5</td>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>P5</td>
<td>6</td>
<td>9</td>
<td>30</td>
</tr>
<tr>
<td>P6</td>
<td>6</td>
<td>9</td>
<td>30</td>
</tr>
<tr>
<td>P7</td>
<td>5</td>
<td>9</td>
<td>40</td>
</tr>
<tr>
<td>P8</td>
<td>4</td>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td>P9</td>
<td>5</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>P10</td>
<td>4</td>
<td>9</td>
<td>50</td>
</tr>
<tr>
<td>P11</td>
<td>5</td>
<td>9</td>
<td>40</td>
</tr>
<tr>
<td>P12</td>
<td>6</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>P13</td>
<td>7</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>P14</td>
<td>8</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>P15</td>
<td>8</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>P16</td>
<td>5</td>
<td>8</td>
<td>30</td>
</tr>
<tr>
<td>P17</td>
<td>8</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>P18</td>
<td>6</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>P19</td>
<td>6</td>
<td>9</td>
<td>30</td>
</tr>
<tr>
<td>P20</td>
<td>6</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>P21</td>
<td>7</td>
<td>9</td>
<td>20</td>
</tr>
<tr>
<td>P22</td>
<td>6</td>
<td>9</td>
<td>30</td>
</tr>
<tr>
<td>P23</td>
<td>4</td>
<td>9</td>
<td>50</td>
</tr>
<tr>
<td>P24</td>
<td>5</td>
<td>9</td>
<td>40</td>
</tr>
<tr>
<td>P25</td>
<td>6</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>P26</td>
<td>6</td>
<td>9</td>
<td>30</td>
</tr>
<tr>
<td>P27</td>
<td>8</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>P28</td>
<td>5</td>
<td>8</td>
<td>30</td>
</tr>
<tr>
<td>P29</td>
<td>6</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>P30</td>
<td>8</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Mean</td>
<td>5.90</td>
<td>8.60</td>
<td>27</td>
</tr>
</tbody>
</table>
Based on the result obtained in Table 5.0, it shows the increase of the score after the CLT method being applied in the system.

The highest score for the pre-test by users P14, P15, P17, P27 and P30 is 8 marks whilst for the post-test the score for users P9, P14, P15 and P30 is 10 marks or in other words, full marks. The lowest score for the pre-test by users P8, P10 and P23 is 4 marks whilst for the post-test the lowest score for users P1 and P4 is 7 marks.

The highest percentage for the difference between pre-test and post-test from users P9, P10 and P23 is 50% and the lowest percentage came from the P13 user that is 10%. The average score achievement between pre and post-test is 27%.

a) Different achievement between Pre-test and Post-test data by users using t-test.

Difference between pre and post test score among users being conducted by using \textit{t-test}. The \textit{t-test} is used to compare the values of the means two samples (pre-test score and post-test score) among users. Table 5.1 shows the output from \textit{t-test} on the effectiveness of the courseware that used the Cognitive Load Theory based model focused on the pre and post-test score.

Based on the table 5.1, the mean score for pre-test is 5.90 (Standard Deviation = 1.2134) and the mean score for post-test is 8.43 (Standard Deviation = 0.8137), number of users are N=30. The result shows, $t = -10.124$ dan $p = 0.000$ (p<0.05).

It means that, there is a significant difference in user’s achievement score after the user used the courseware with the CLT application.
Table 5.1: t-test value for pre and post-test for the Mathematics courseware using the CLT based model.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-test score</strong></td>
<td>30</td>
<td>5.90</td>
<td>1.213</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Post-test score</strong></td>
<td>30</td>
<td>8.60</td>
<td>0.814</td>
<td>-10.124</td>
<td>0.000*</td>
</tr>
</tbody>
</table>

* significant value $p < 0.0005$

b) Output from Pre-test and Post-test Score.

The results from the pre and post test conducted can be viewed from Table 5.2. There is a difference between mean score for pre-test and post-test, also mean for score achievement. Table 5.2 displays the mean score for post-test higher than the mean score for pre-test score. By looking at the output, this difference is considered to be extremely statistically significant.

Table 5.2: The difference between pre and post test score.

<table>
<thead>
<tr>
<th></th>
<th>Mean Score for Pre-Test</th>
<th>Mean Score for Post-Test</th>
<th>Mean of Score Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Users</td>
<td>5.90</td>
<td>8.60</td>
<td>27</td>
</tr>
</tbody>
</table>

5.2.2 Interface Design

There are two types of questionnaires involved for this project, pre development (Set A) questionnaires and post development (Set B) questionnaires. Set A questionnaires was distributed before the prototype has been completed, whereby the Set B questionnaires is distributed after the prototype has been completed. Twenty five of the thirty participants were observed while using Mathematics courseware. All six teachers identified Mathematics courseware meet the standards that were intended to be integrated. None of the teachers argued on the design part, moreover they like the graphic and animation.
Based on the first question asked for the Set A questionnaires, 98% of the respondents strongly agree that Mathematics is one of the important subjects in school, therefore by learning the subject through the courseware as an additional reference material, it can attract interest among students. These can be seen through the combination of multimedia elements such as the colorful graphics, animation and voice over that had been embedded in the courseware.
90% of the respondents strongly agreed that Quadratic Function is the topic that need a
good explanation to deliver the content. This answered the second question of Set A
questionnaires.

Third graph shows on the cognitive load theory, whether the explanation on the content
is better been expressed by providing with both media and graphic rather than the text
or audio alone. 95% of the respondents strongly agree with the above statement whilst
5% of the respondents agree with the statement.

For the Set B questionnaires, forth graph shows the use of multimedia elements such as
graphics, audio and animation may attract attention from the students. 2% of the
respondents agree with the statement. From this feedback, the conclusion can be made
was the multimedia element mainly for the courseware development should have this
criteria like colorful graphic, clear explanation on content itself and animated character.

The fifth graph shows about the division of the section in the courseware. This
courseware is divided into four sections that are Isi kandungan (content), Aktiviti
Pembelajaran (Learning activity), Latihan (exercise) and Ujian Formatif (formative
test). 95% of the respondents strongly agree with this division and 5% agree. The
divisional of each area section has its own reason. For Isi Kandungan, users learn the
content of Quadratic Function, whilst for Aktiviti Pembelajaran (Learning Activity) and
Latihan (exercise), users can interact with the courseware by trying the activities
provided. One of the questionnaires stated that the learning process can be enhanced
when pictorial and spoken materials were presented concurrently rather than
sequentially.
Majority of the respondents strongly agreed with this statement. Based on the feedback from the respondents, it can be concluded that this point is based on the research done by Mayer and Sims (1994). All the participants were self-motivated and they managed to go through the courseware on their own without any help.

### 5.2.3 Findings - Interviews

Interviews had been conducted to complete this project. There are five teachers sat for the interviews from five different places in Klang Valley and Penang area. The schools were Sekolah Menengah Damansara Damai, Petaling Jaya, Sekolah Menengah Taman Desa, Rawang Selangor and Sekolah Menengah Alma, Bukit Mertajam, Penang. The questions for the interviews can refer to the attachment at appendix C.

From the result, I can conclude that all the teachers agreed that this Mathematics courseware can be used as an additional reference material for the students to do their revision outside the classroom.

Moreover, this courseware followed the school syllabus, therefore, it would not give any problems to the students whether the content can be used or not. The presentation of the content was very interesting and made the students felt comfortable and convenience while doing the exercises. The way it explained and gave the examples can reduced the Cognitive Load of the students. They can understand the concept easily because it was presented in the proper manner as suggested by Sweller in his researched. For instance, Use relevant graphics explained by Audio Narration to communicate content.
In addition, all the teachers were impressed with the activities designed in the courseware. There were varieties of activities such like fill in the blanks, click and drag and drop. They felt that the students definitely will not get bored because of these activities.

The interactivity styles like fill in the blanks, drag and drop are the multimedia criteria that can attract attention from the students said Mrs. Zuraime Ismail. They have variety of interactivity styles to test on. 85% strongly agree that the interactivity styles are really interesting because it is non-linear means that user has their own preferences to navigate anywhere the like, 10% agree and the rest 5% stated that it just fair enough that the interactivity styles are interesting.

The Mathematics Courseware Acceptance Test Plan is a specific document detailing the Acceptance Test procedure to be adopted to test the functionality of Secondary Mathematics courseware based on the Cognitive Load Theory based model and storyboard.

5.3 Discussion

Student’s task in solving Mathematics complexity increase as well as the information velocity and ubiquity. Cognitive task analyses are needed to realize an adequate human resource deployment by training, selection, task allocation and cognitive support system.

Methods based on Cognitive Load Theory are still in research state. To enable well-founded analyses in such task environments, I have developed a CLT model. Recently, I developed a prototype on the learning courseware by assessing the contents in different
task allocation and support functions. The CLT model in this courseware allows a systematic learning capabilities, qualitative comparison of design for task contexts, showing the relative consequences of design choices for instance I have design the content of the learning courseware in few sections do that every section will have different load of working memory. For instance, Latihan (exercise) section, Aktiviti Pembelajaran (Learning Activity) section, Latihan (exercise) section and Ujian Formatif (Formative test) section. Out of these three, Learning Activity has the lowest Cognitive Load because student only input the content and concept. Whilst at the Aktiviti Pembelajaran (Learning Activity) section and Ujian Formatif (Formative test) section the students need to simulate whatever they had learnt and translate them in these two activities form.

The current version of the tool, however, needs further improvement with respect to its usability and empirical foundation.

5.4 Conclusion

Evaluation and testing phase are necessary as it ensures that feedback gathered is both defined and accurate and that subsequent decisions based on arguments embodied in the findings are valid. The process provides both a baseline from which to measure from and in certain cases a target on what to improve. Without the feedback from the users, the system might not be usable. 95% of the teachers agreed that the syllabus used, helped students gain better understanding of the Mathematical concept explained by the system. Moreover, most of the students found that the used of colorful graphic, image and animated characters can attract attention from them. All the participants were self-motivated and managed to go through the courseware on their own without any help.
Unit and System test are carried out to check the conformance with approved storyboard, addendum and courseware convention. Errors are compiled for correction. Retest is performed until all the errors are fixed. After all the errors are fixed, the courseware is ready to use by the users. Users will raise the errors (If any) inside the courseware review form. Retest process are carried out until all the errors had been fixed.
CHAPTER 6

CONCLUSION

6.0 Introduction

Creativity in teaching and learning Mathematics in the classroom provides room for the development of the student’s potential such as increasing interest, sharpen talents and ability, increase various skills as well as provide satisfaction to the individual to obtain success. The flow of creative ideas and innovations in teaching and learning Mathematics can expand students creative thought process. The use of various methodologies or pedagogy can nurture creativity in learning the subject.

The courseware is interactive education resources that offer an alternative to conventional study materials. Developed based on the National Education Philosophy and the Smart School curriculum, it encourages self paced, self assessed and self directed learning styles.

6.1 Research Contributions

Multimedia courseware such like mathematics subject help students to create dynamic, well-organized and student-centered experiences in class. By considering the Cognitive Load theory, it can be used to support mathematical understanding in an interactive learning environments.
This Cognitive Load Theory based model courseware can be used as a guideline by teachers to give the students another alternative to learning the quadratic function topic. For example, by providing the multimedia elements such as graphics and audio followed by animation make the student’s understanding towards the subject better, as Mayer (1997) stated in his theory that the screen itself should be designed by the designer either with pictorial or text in order to make the courseware understandable. In addition, the interface produced by this courseware is more structured. Again, Mayer (1997) agreed that learning can be enhanced by displaying the graphic images and voice over concurrently with the text.

This CLT courseware can be used as a reference for developers who are looking to develop courseware for instructional design area such as complex problem-solving environment, worked-example instruction and multimedia learning. As Boon, T.B. (2006) stated, Quadratic function is one of the complicated topics in secondary school syllabus. Students learn better at solving mathematics problem when they study worked-examples than they solely engage in hands-on problem solving.

By using this courseware, there is less storage consumption because this is not online learning tool or involved database application whereby users normally face the network traffic. Hence, this courseware which utilizes CLT in many aspects demonstrates how the learning process can be made easier and simpler and in the end benefit the students.

6.2 System Limitations

Even though this Mathematics courseware may contribute positive impact to the users, but there are a few limitations that this courseware had, for instance: Firstly, the
courseware use *Malay language* as the medium of instruction, and hopefully this courseware can be developed using English language too.

Secondly, this courseware is a standalone system, it can be enhanced by providing the online learning tool also in future.

Last but not least, the expectations from the students maybe high in terms of the use of multimedia elements like 3D animations or graphics. In order to produce or design a character of 3D graphic image, the best quality of 3D software is needed to achieve the requirements from the users. However, the high cost of the 3D software caused lack of 3D objects development.

### 6.3 Recommendations and Further Study

Future research should include a study of the integration of other subjects too. Instead of standalone, the courseware should be available online so that the students may access through the website at their own convenience.

The integration with database will make the online learning more comprehensive. For instance students may view their level of performance toward the subject from time to time. Their record will be kept in the database. Moreover they can access the record to view their marks.

### 6.4 Conclusion

Mathematics courseware is an additional reference material where its interactive use of multimedia methods ensures total understanding of various subject matters and stresses
on creative and critical thinking. So basically, cognitive load theory says that we cannot control the difficulty of WHAT is to be learned, but HOW it is learned. Instructional materials should be presented to the learner to optimize the capacity of their working memory. At this point, it is an important to note that for an instructional design to be effective, learners should also be motivated or willing to invest mental effort in it (Paas, et al., 2003). Eventually, CLT may offer another viewpoint on assessment and task selection. Clearly, the same level of performance can be assessed differently depending on the amount of mental effort that is necessary for reaching it. The best new learning task for a person who is accomplishing a high level of performance with a very low investment of mental effort be different from the best new learning task for a person who is reaching the same level of performance with a very high investment of mental effort.

After all findings are reviewed, the conclusion can be made that this project meet the objectives. For example, first objective for this research is to research how Cognitive Load Theory can support learning and understanding Mathematical concept. Students at Sekolah Menengah Damansara Damai said that their Mathematics skill had increased based on the CLT method used. They enjoyed running the system with the colorful graphics, animation and voice over. The screen designs are very attractive and the interactive environment makes the users feel excited while using the courseware. Based on the result obtained from the questionnaires, it shows that 95% of the respondents strongly agree the use of multimedia elements in the courseware and the use of CLT increase their understanding the concept of quadratic function.
The second objective is **to design and develop a prototype on Mathematics courseware based on the Cognitive Load Theory method in an interactive environment.** This mathematics prototype used by the teachers and students at Klang Valley schools as one of the additional reference material. The survey had been conducted on the prototype to see the effectiveness of the courseware. The positive response from the users showed that the courseware can be used by the students as an alternative besides the text book. **95%** of the respondents **strongly agree** that the prototype designed for this particular courseware give the additional reference material to the students. By having the quadratic function courseware, students can do their revision outside the class at their convenient time.

Eventually, the third objective of this research is **to evaluate the feasibility of supporting student learning using CLT based prototype.** This objective is achieved by looking at the findings of the questionnaires. Again, Mayer (1997) agreed that learning can be enhanced by displaying the graphic images and voice over concurrently with the text. The results from the findings on the question 10 shows that **98%** of the respondents **strongly agree** on Mayer’s statement that users do not have the passion to learn the subject if there is only static text displayed on the screen. Based on the result obtained from the questionnaires, it shows the increase of the score after the CLT method being applied in the system. the mean score for post-test higher than the mean score for pre-test score. By looking at the output of the *t*-test, this difference is considered to be extremely statistically significant. The statistics shows the increase of the percentage before and after the development of the prototype. The increase of the Mean score that is 27% shows that Cognitive Load Theory has the positive impact on the courseware itself.
Three techniques suggested to help optimize the cognitive load in designing computer based instruction.

- Split-attention effect or unnecessary sources of information that compete for cognitive load and reduce schema acquisition. These unnecessary sources should be minimized.
- Redundancy effect or content that is repeated unnecessarily. Each instance of redundant information places additional demand on cognition.
- Modality effect, which increases working memory capacity by combining audible and visual information.
REFERENCES


Pre - Development Questionnaires

Topic: Cognitive Load Theory Based Model in Mathematics Software

Mathematics Form Four: Quadratic Function

Student Name: _______________________________________________

School: ______________________________________________________

Please write down the answer in the boxes provided.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Fair</td>
<td>Do not Agree</td>
<td>Strongly Disagree</td>
</tr>
</tbody>
</table>

1. Mathematics is one of the important subjects in school. Therefore, by learning the subject through the courseware it can increase the interest among students.  

2. Quadratic Function is a topic that needs a good explanation to deliver the content to the students.  

3. The clear explanation with the graphic or animation can attract attention from the students. These can reduce the Cognitive Load memory because student can easily visualize the formula such as the diameter, radius and area of the Quadratic Function.  

4. The explanation on the content is better been expressed by providing with both audio and graphic rather than the text or audio alone.  

5. Most of the courseware in the market follow the pedagogy that is the syllabus and the content provided at school.
Post - Development Questionnaires

Topic: Cognitive Load Theory Based Model in Mathematics Software

Mathematics Form Four: Quadratic Function

Name: ____________________________________________

School: ____________________________________________

Please write down the answer in the boxes provided.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<tbody>
<tr>
<td></td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Fair</td>
<td>Do not Agree</td>
<td>Strongly Disagree</td>
</tr>
</tbody>
</table>

6. The use of multimedia elements such as graphics, audio and animation may attract attention from the students.

7. The courseware is user friendly, where user can easily access the courseware that provides the understandable multimedia elements such as navigation buttons/boxes, animated characters, etc.

8. The syllabus for the whole courseware follows the school contents.

9. The activities and exercises provided in the courseware such as click, drag and drop able to gain interest from the students in learning Quadratic Function subject.

10. Users do not interested in learning the Quadratic Function, which only provide the static image.

11. The courseware is divided into four sections that are the Learning Activity 1, Learning Activity 2, Progress Check and Diagnostic Check. Do you agree with these four categories?
12. The interface of this courseware for example, the text and graphic displayed give a good impact to the student in terms of visualizing the concept of Quadratic Function.

13. By displaying the graphic, animation and text on the same screen, it can reduce the cognitive load memory of the users. It means that user can understand the concept better compared to the traditional method where teacher will use board and chalk to explain the concept to the students.

14. The instruction given by the courseware in the Learning Activity 1 and Learning Activity 2 sections are clearly explained.

15. Please state the efficacy and students' ability to solve the Mathematics tasks, with the proposed concept (or) Please state how easy the Mathematics task given being solved by the student
Test Questions

**Topic: Cognitive Load Theory Based Model in Mathematics Software**

**Mathematics Form Four: Quadratic Function (Fungsi Kuadratik)**

Student Name: _______________________________________________

School: _______________________________________________________

Tentukan julat nilai x untuk soalan-soalan berikut. Heret jawapan yang betul ke ruangan yang disediakan. (10 markah)

<table>
<thead>
<tr>
<th>Soalan</th>
<th>Expression</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.</td>
<td>$6 - 2x &lt; 0$</td>
<td>$x &gt; 4$</td>
</tr>
<tr>
<td>17.</td>
<td>$3y - 2 = 4x$ dan $y &gt; 6$</td>
<td>$y &gt; 3$</td>
</tr>
<tr>
<td>18.</td>
<td>$(x + 4)(x - 3) \leq 0$</td>
<td>$-4 \leq x \leq 3$</td>
</tr>
<tr>
<td>19.</td>
<td>$(x - 1)(x + 3) &gt; 0$</td>
<td>$x &lt; \frac{1}{2}, x &gt; 3$</td>
</tr>
<tr>
<td>20.</td>
<td>$2x^2 - 7x + 3 &gt; 0$</td>
<td>$x &lt; -3, x &gt; 1$</td>
</tr>
<tr>
<td>21.</td>
<td>$-x^2 + 5x + 6 \leq 0$</td>
<td>$-3 &lt; x &lt; \frac{1}{2}$</td>
</tr>
<tr>
<td>22.</td>
<td>$(8x - 2)x &lt; 1$</td>
<td>$-\frac{1}{4} &lt; x &lt; \frac{1}{2}$</td>
</tr>
<tr>
<td>23.</td>
<td>$(x + 3) &gt; (x + 3)^2$</td>
<td>$x &lt; -8, x &gt; 2$</td>
</tr>
<tr>
<td>24.</td>
<td>$(x - 2)(2x + 5) &gt; (x - 3)(x - 2)$</td>
<td>$\frac{1}{3} \leq x \leq 3$</td>
</tr>
<tr>
<td>25.</td>
<td>$3(x^2 + 1) \leq 10x$</td>
<td>$x \leq -1, x \geq 6$</td>
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### ADDENDUM FORM

**Subject**: Mathematics

<table>
<thead>
<tr>
<th>Courseware Title</th>
<th>Fungsi Kuadratik Tingkatan 4</th>
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#### Test Result (Findings)

<table>
<thead>
<tr>
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<tr>
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<tr>
<td>Name</td>
<td>Name</td>
</tr>
<tr>
<td>School Name</td>
<td>School Name</td>
</tr>
<tr>
<td>Date</td>
<td>Date</td>
</tr>
</tbody>
</table>

- [ ] Pass
- [ ] Fail

Remarks:

___________________________

___________________________
# DECLARATION OF READINESS FOR CONTENT REWORK

(Should be submitted before 30th December 2010)

## DETAILS

<table>
<thead>
<tr>
<th>Developer Name</th>
<th>Erni Marlina binti Saari</th>
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<tr>
<td>Test Venue</td>
<td>Sekolah Menengah Damansara Damai, Petaling Jaya</td>
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<tr>
<td>Start and Completion Date of test</td>
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<td>Date of this Declaration</td>
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## SIGNATORIES

I, the undersigned, declare that all information provided in this statement is accurate as at the date of this declaration.

Signature: ___________________________  Signature: ___________________________

Name: Erni Marlina Saari  Name: Mrs. Mas Idayu Sabri

Position: Developer of the Courseware  Position: Supervisor

Date: ___________________________  Date: ___________________________

## DECLARATION CHECKLIST

<table>
<thead>
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<th>DOCUMENT NAME (Relevant Doc)</th>
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<th>AVAILABILITY</th>
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<tbody>
<tr>
<td>Test Plan &amp; Test Procedure</td>
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<tr>
<td>Installation Procedure</td>
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## The Following INTERNAL TESTS have been carried out

<table>
<thead>
<tr>
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<th>TEST RESULTS DOC ID</th>
<th>TEST DATES</th>
<th>AVAILABILITY</th>
<th>INTERNAL VERIFICATION STATUS</th>
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<tr>
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