Designing multimedia learning application with learning theories: A case study on a computer science subject with 2-D and 3-D animated versions

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Contents

Abstract

Higher learning based instruction may be primarily concerned in most cases with the content of their academic lessons, and not very much with their instructional delivery. However, the effective application of learning theories and technology in higher education has an impact on student performance. With the rapid progress in the computer and multimedia technologies, it has become feasible to integrate multimedia technologies into the teaching and learning process. What has been the conventional teacher-centered teaching approach is now seeing a shift into one which emphasises on student-centered learning approach. There is a body of evidence that supports the benefit of using technology, such as multimedia elements in the form of 2-Dimension (2-D) and 3-Dimension (3-D) animation to assist in learning. The domain knowledge applied in this study was on a Computer Science subject, particularly on Operating Systems, for the topic on 'Memory Management'. Memory management is one of the topics taught in the course on Operating Systems in Computer Science and Information Technology programmes. This paper discusses the applicability of some learning theories, Mayer's Cognitive theory of Multimedia learning, and the use of animation in computer science education. Finally screen designs of the multimedia learning prototypes are displayed in 2-D and 3-D animation.

Keywords: Computer science education, learning theories, instructional design, animation

Introduction

Education is important; whether it is at the primary, secondary or even at the tertiary/ university level. The government of Malaysia has put in a great deal of emphasis on educating the population, at least at the primary and early secondary level. It is now an undisputed fact that many learning institutions are finding new means to traditional methods in order to bridge learning efficiency with technology. "Universities today are in transition. Much of the change we see is driven by economic pressures and demand for graduates who will be able to function in a knowledge society" (Franklin and Peat, 2001). The growing awareness amongst educators has resulted in the diversification of learning and teaching processes in these changing times. In Malaysia, the institutes of higher learning are currently moving towards a more multimedia oriented classroom (Teoh and Neo, 2006).

Traditional educational content can now be transformed into interactive multimedia content by using authoring packages (Roselli et al., 2003). This fact has enabled the teacher to innovate their instructional designs by presenting the education content in an interactive and multi-sensory manner rather than the traditional single media format. This infusion of multimedia into teaching and learning has altered instructional strategies in educational institutions and many colleges and universities, including those in Malaysia are currently gearing their teaching and learning towards one which uses multimedia technology to enhance the student's learning process (Teoh and Neo, 2006).

Developing effective materials (in any medium) that facilitates learning requires an understanding and appreciation of the principles underlying how people learn. Just as engineering is the application of basic principles from physics and chemistry, and as medicine is the application of basic principles of biology, instruction is the application of basic principles of learning (Alessi and Trollip, 2001).When a developer plans to develop an educational courseware or an e-learning application, the principles of learning to apply to the application should be thought about first.

The subject that was chosen to be the domain of this study was a topic in computer science education, which is Operating Systems, specifically on 'Memory Management Concepts'. Operating Systems (OS) is a field studied in Computer Science, Information Science and Computer Engineering. Some of its topics require a careful and detailed explanation from the lecturer, as they often involve many theoretical concepts and somewhat complex calculations, demanding a certain degree of abstraction from the students if they are to gain full understanding. The traditional course model prepares and exhibits slides and presents some theoretical exercises has been found to be insufficient, to assure a précised comprehension of what is being taught and without a practical vision, the students tend to lose touch of the introduced concepts (Maia et al., 2005) . Sample prototypes were developed displaying learning content in two versions: 2-D animation and 3-D animation .The prototypes that were developed for this study was given the name OSIMM (Operating Systems in Memory Management).

This paper first discusses on the learning theories applied in this study, then Mayer's Cognitive theory of multimedia learning is explained , thirdly, the use of animation is discussed, and finally, screen design of the prototypes (OSIMM) are shown.

Learning Theories

In today's scenario, computer-based education has become popular and students want to learn on their own with the computer and the teacher acts as a facilitator. Every learning theory has its own concepts and views on learning. Clark (1983) stated that there has been a paradigm shift in the development of education that is from the behaviourist theory to the cognitive and constructivist theories point of view. The following subsections describe these three primary principles in learning. Understanding these principles is essential in order to understand the materials being designed in this study.

2.1 Behavioural Theory

Edward Thorndike and Ivan Pavlov (Mok, 2002) studied behaviourism in the turn of the twentieth century. The theory of behaviourism basically means that every response to a conditional stimulus is a conditioned response. The implication is that humans learn many behaviours because of their pairing with basic human needs and responses, such as the need for food, sleep, reproduction, and the like. The use of reward and punishment is also said to be a part of modifying a behaviour. This work was refined and popularised by B.F. Skinner (Alessi and Trollip, 2001) and gave rise to the behavioural school of psychology and learning. Some of the basic behavioural rules are as follows:

i. Behaviour that is followed by positive environmental effects (known as positive reinforcement or reward) increases in frequency.
ii. Behaviour that is followed by the withdrawal of negative environmental effects (known as negative reinforcement) also increases in frequency.
iii. Behaviour that is followed by a negative environmental effect (punishment) decreases in frequency.
iv. When behaviour that was previously increased in frequency through reinforcement is no longer reinforced, it decreases in frequency (known as extinction) (Source: Alessi and Trollip, 2001).

According to Hartley and Davies (1978), a few of these behaviourism principles were used widely in education which includes the following:

i. Learning process becomes easier when students follow the active process of learning.
ii. Learning materials are arranged in logical order to ease students' learning and encourage feedback.
iii. Each response must have immediate feedback for students to learn from their mistakes.
iv. Each student response must be given a positive or negative reinforcement.

The implication of behavioural theory to this research is inevitable. The display of topic and subtopics must be well structured to assist in smooth learning. Even though the system developed for this study has no direct response to students, nevertheless, the concept of behaviourism is applied throughout the system. The learning process of the system developed is in-par with the objectives and in order with the level of difficulty from less thorough to most difficult. Although behaviourist systems promote teacher-centered learning, this system promotes a student-centered learning environment, which integrates the positive principles of behaviourism with a cognitive-constructivist approach.

2.2 Cognitive Theory

Cognitive theory takes its name from the word cognition, which means the process of knowing. Cognitive psychology puts emphasis on unobservable constructs, such as the mind, memory, attitudes, motivation, thinking, reflection, and other presumed internal processes. The most important study in cognition is based on information-processing approach. In computer science, information processing theories attempt to describe how information in the world enters through our senses, becomes stored in memory, is retained or forgotten, and is used. Most information processing approaches include the notion that memory and thinking have a limited capacity, which accounts for failures in attention and in memory. Also included is the notion of an executive control, which coordinates the learner's perception, memory, processing, and application of information. Another part of cognitive psychology is semantic network. This theory attempts to parallel how biologists view the connections of the human brain. In the semantic network such as the brain, learning may be represented by removing or adding links between nodes or by creating or changing nodes. For example, new knowledge may be so surprising that people interpret the new information in a way that is congruous with existing knowledge or beliefs. But this new knowledge may become so clear that eventually, existing knowledge must also change to remain acceptable in light of the new knowledge (Alessi and Trollip, 2001; Simonson et al., 2003).

Prominent figures in cognitivism such as Bruner, Piaget and Papert gave emphasis on concepts as follows (Simonson et al., 2003):

i. How knowledge is arranged and structured.
ii. Students' readiness to learn.
iii. Give importance to intuition and intellectuality.
iv. Motivation and positive outlook on learning.

The implication of cognitivism towards this study is that the content of the learning subject and the way it is presented is given emphasis. The topic in the system is displayed in a systematical order. Each slide is numbered and each subtopic allows students to use the back and forward arrows for re-learning and strengthening their memory. According to the cognitive theory, humans need to see things in a concrete manner to understand better. The objective of the learning subject is told at the beginning of the slides. As students browse along, they will see a proper sequence to the learning process.

2.3 Constructivist Theory

Constructivism is where each individual learner combines new information with existing knowledge and experiences (Jonassen, 1999). Constructivism is also a philosophical view. The objectivist philosophy, or world view, hold that there is an objective world that is perceived more or less accurately through the senses, and that learning is the process of correctly interpreting the senses and responding correctly to objects and events in the real world.
Constructivism is a relatively recent branch of cognitive psychology that has had a major impact on the thinking of many instructional designers. Constructivist thinking varies broadly on many issues, but the central point is that learning is always a unique product 'constructed' as each individual learner combines new information with existing knowledge and experiences. Individual have learned when they have constructed new interpretations of the social, cultural, physical, and intellectual environments in which they live (Dick and Carey, 2005).

There are different schools of constructivism thought. For example, according to social constructivism, learning is inherently social. What we learn in a function of social norms and interpretations, and knowledge is not simply constructed by the individual, but by social groups. Moderate constructivism maintains that there is indeed a real world but that our understanding of it is very individual and changing. More radical constructivism holds that we can never really know the exact nature of the real world, so it is only our interpretations that matter.

One of the more substantial aspects of constructivist thinking is the basis of situated learning (Moore et al., 1994). The theory of situated learning assumes that learning always occurs in certain context, and the context in turn significantly affects learning. The main implication of situated learning theory is that when properly designed, the situation in which learning takes place enhances transfer to other settings.

The anchored instruction approach is closely related to situated learning and is often attributed to one another. Anchored instruction assumes that a learning environment should be embedded in a context that is like the real world: with real world imagery, goals, problems, and activities (Alessi and Trollip, 2001). Proponents of the constructivist approach maintain that designers should be creating educational environments that facilitate the construction of knowledge.

There are various principles or suggestions that typically promote ways to accomplish that goal and they are as follows (Alessi and Trollip, 2001):

i. Emphasise learning rather than teaching.
ii. Emphasise the actions and thinking of learners rather than of teachers.
iii. Emphasis to active learning.
iv. Use discovery or guided discovery approaches.
v. Encourage learner construction of information and projects.
vi. Have a foundation in situated cognition and its associated notion of anchored instruction.
vii. Use cooperative or collaborative learning activities.
viii. Use purposeful, real or authentic learning activities.
ix. Emphasise learner choice and negotiation of goals, strategies, and evaluation methods.
x. Encourage personal autonomy on the part of the learners.
xi. Support learner reflection.
xii. Support learner ownership of learning and activities.
xiii. Encourage learners to accept and reflect on the complexity of the real world.
xiv. Use authentic tasks and activities that are personally relevant to learners.

The implication of using constructivism in this study is immense. Constructivism basically combines new information with existing knowledge and experiences. Therefore, in this research, the development of multimedia animation and static pictures had implemented this concept. For example, at the beginning of the slides, students were shown a cinema sitting. They were told that each sitting in a cinema is mutually exclusive and no two persons will have to share a seat. The same concept is applied in memory management, where each data is given a specific address. The analogy used in the cinema sitting scenario is then repeated in a few slides for recall purposes. The usage of a truck is used to carry data into a large rack. This concept is used so that students can relate the usage of a truck in a store at a hypermarket to store supplies with the same idea related to contiguous memory allocation in a CPU. Furthermore, an excavator concept was used in the slides for the purpose to carry data from the logical address to a physical address, with the idea that students can relate to the actual scene of an excavator carrying heavy bricks from one place to another to build a highway. All these concepts are part of constructivist approach to learning.

2.4 Cognitive-Constructivist Approach - Student Centered Learning

Gibbs (1992) defined student-centered learning as that which, “gives students greater autonomy and control over the choice of subject matter, learning methods and pace of study”. In other words, learners can dictate their own learning relevant to their own approaches. Student-centered learning derived its meaning in a learning environment where knowledge is built and achieved by means of student’s active participation in the learning activities. Students do not passively listen and absorb the delivered information, but learn through a series of discoveries, interactions, inquiries and problem-solving situations they actively engage in (Neo and Neo, 2004).In the student-centered learning mode, there is a need for goals to be set and learning process to be managed. They can no longer rely on the lecturer to tell them what, how, where and when to think. Students should be able to actively choose programmed components in whatever desired order, rather than simply work through a predetermined course of study (Andrewartha and Wilmot, 2001). If teachers were information keepers in a traditional classroom, in a student-centered concept, students were active information seekers. Therefore, researchers have defined student-centered as active learning, learning by ‘doing’ rather than of passive watching or listening.

In order to design such an environment, interactivity is embedded in the learning environment. Ambron (1990) suggests, interactive learning is student-centered learning. In addition, interactive multimedia can be designed to allow users to access information according to their unique interests (Reeves, 1992). The most important goal for adding interactivity is to provide the learner with the choice to decide where to explore first within the application at his or her own pace. Liaw (2001) posits that the hypermedia-based applications are non-linear and allows learners to explore information in their own ways. While Kappe, Maurer and Sherbakov (1993) suggested that hypermedia is the force that puts all previous educational technologies in the shade. Laurillard (1993) agreed that hypertext is controllable by the user and this is the medium’s real strength. As Lambert Gardiner (1993) argued, hypermedia feature in multimedia applications is educationally superior to traditional media because it simulates the real life situation of the students. Just as in real life situation, students are dealing with information from many sources, with interactivity and hypermedia, learners are able to navigate through the application in a non-linear fashion and are able to view topics of interest directly rather than simply viewing a linear presentation. Thus, by allowing students to explore the module on their own in a non-linear fashion, students can learn better in a student-centered environment.

Mayer's Cognitive Theory of Multimedia Learning

3.1 The Multimedia Learning Model

Based on the multimedia learning model in Figure 1, the arrows represent the steps of processing involved in the cognitive theory of multimedia learning: (a) selecting relevant words, (b) selecting relevant images, (c) organising selected words, (d) organising selected images, and (e) integrating verbal and visual representation as well as prior knowledge

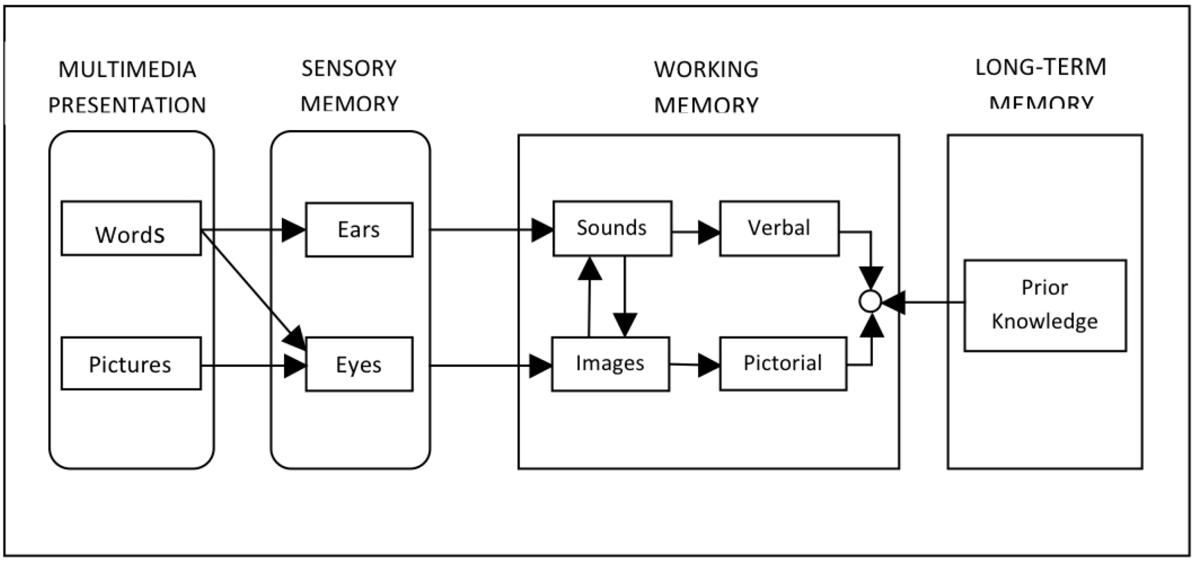


Figure 1: Visual Representation of the Cognitive Theory of Multimedia Learning (Source: Mayer 2001)

Mayer's (2001;2009) experiments were focused on the auditory/verbal channel and the visual channel. He defines multimedia as the presentation of material using both words and pictures. Thus, the definition of multimedia is narrowed down to two forms of information: verbal and pictorial or visual. This is because the research base in cognitive psychology is most relevant to this definition.

This model is based on three primary assumptions (Mayer 2009) as follows:

i. Visual and auditory experiences or information are processed through separate and distinct information processing 'channels'.
ii. Each information processing channel is limited in its ability to process experiences or information.
iii. Processing experiences or information in the channels form an active process designed to construct coherent mental representations.

Throughout the 1990s and beyond, Mayer and his colleagues have conducted research investigating the nature and effects of multimedia presentations on human learning. Mayer's (2001;2009) theory on multimedia learning involves seven principles that can be applied for the design of multimedia messages as indicated in Figure 2.

1. *Multimedia Principle*: Students learn better from words and pictures than from words alone.
2. *Spatial Contiguity Principle*: Students learn better when corresponding words and pictures are presented near rather than far from each other on the page or screen.
3. *Temporal Contiguity Principle*: Students learn better when corresponding words and pictures are presented simultaneously rather than successively.
4. *Coherence Principle:* Students learn better when extraneous words, pictures, and sounds are excluded rather than included.
5. *Modality Principle*: Students learn better from animation and narration than from animation and on-screen text.
6. *Redundancy Principle*: Students learn better from animation and narration than from animation, narration and on-screen text.
7. *Individual Differences Principle*: Design effects are stronger for low-knowledge learners than for high-knowledge learners and for high-spatial learners rather than for low-spatial learners.

Figure 2: Seven Research-based Principles for the Design of Multimedia Messages (Adapted from Mayer 2001)

Mayer's theories were applied throughout, in the design and development of the prototypes for the topic of memory management in Operating Systems Concept (OSIMM).

Use of Animation in Computer-Based Instruction

Animation in computer-based instruction holds powerful instructional potential. Instructional animation is used in computer-based instruction to accomplish one of three functions: attention-gaining, presentation and practice (Rieber, 1990). According to Park and Hopkins (1993), animation in visual display fulfils five instructional roles: as an attention guide; as an aid for illustrating functional or procedural behaviour: as a representation of domain knowledge entailing movement; as a device model for forming a mental image of system functions which are not directly observable; and as a visual analogy or reasoning anchor for understanding abstract concepts. Computer graphic technology including innovative capabilities previously unavailable through printed text or still pictures is strategically applied in instruction with rationales. It is presenting new challenges to traditional educational practice. Three major rationales to employ animation in computer-based instruction are as discussed below:

i. Representation of Movement

Animation, like other instructional visuals, should facilitate recall and retention when it illustrates visually-based or spatially-based facts or concepts which are related with movements. Animated graphics are probably much better than static graphics at representing ideas which involve changes over time because of its ability to implement motion, therefore concretising abstract temporal ideas (Rieber and Kini, 1991). If a learning task only requires learners to visualise fixed objects, then the use of static visuals would be sufficient. However, if the learning task requires the dynamic process, a situation in which an element is changing or evolving over time, it is better illustrated through animated visuals.

Most research supporting animated visuals in computer-based instruction were interested in the effects of animation on the learning of dynamic concepts instead of static concepts (Chanlin and Chan, 1996; Mayer, 1994, 1997; Mayer and Anderson, 1994; Mayer and Sims, 1994). Reiber et al. (1990) found positive effects of animated graphics on the learning of Newton's Law of Motion. Mayer (1997) on the other hand, utilised animation to depict causal relationship of the scientific system such as how a bicycle tire pump works; how a braking system works; or how a human respiratory system works. Accordingly, animated graphics is well applied to learn dynamic abstract concepts that are difficult to visualize (Riaza and Halimah, 2009; 2011).

ii. Interaction between Students and Computers

Some traditional visual aids, such as film and videotapes are available to show the motion and dynamic processes. But in many of these film and videotapes, the illustrations are separated by some period of time while students are watching them. Students are not likely able to absorb and process the learning material while sitting in a darkened room and it does not help the learning process (Epstein, 1990). Thus, it would be an advantage if students have at their disposal the visual illustration. It would also be an advantage if students could control the pace and sequence of learning, and interact with the computers. Computers have the unprecedented capability of allowing students to interact with visual illustrations.

Interactive learning takes place in a learning situation where a learner and computer are actively and mutually responding to input/output and adapting to responses (Jonassen, 1999). There are three levels of interactivity according to the way in which users interact with computers (Lucas, 1992). The 'reactive' model which is the lowest level of interactivity draws on behaviourist approach and simply refers to physically pressing the space bar to advance to the next step of program. The 'proactive' model which is based on a cognitive approach is the highest level of interactivity in which the learner is actively engaged in knowledge construction. Recent computer technology enables the instructional designers to develop computer-based or multimedia instructions with proactive model of interactivity. The model between reactive and proactive models is an 'interactive' model, in which the users can branch through the instruction depending on their inputs. They control the sequence of learning program. The animated graphics which are applied in computer-based instructions, involve the proactive model of interactivity, such as those in simulation or interactive 3-dimensional graphics in virtual reality technology.

iii. Attention-guide

According to Rieber (2004), Attention involves cognitive decisions regarding which information to attend to, given the fact that the environment contains far more information than any one person can handle at any given time. Interesting pictures gain and maintain learner's attention in instructional text (Keller and Burkman, 1994). Good pictures motivate learners and encourage curiosity. Pictures including novelty and drama maintain learner's attention (Keller and Burkman, 1994). In this sense, learners can be attracted to animated visuals that include dramatic and unique effects.

One of the important roles of animation as an instructional tool is gaining students' attention (Park and Hopkins, 1993; Rieber, 1991). Gagne, Briggs and Wager (1992) described attention as the first event of instruction. Attention correlates with students' achievement more highly than the time-to-learn and poor learners have poor attention (Mayer and Wittrock, 1996). The presentation of highly visual material is an effective teaching technique for arousing and sustaining student's attention (Hativa and Reingold, 1987).

Attention-gaining is an obvious, practical and rational use of animation. Rapidly changing visuals can be displayed on a computer screen to grab students' attention, such as cartoon figures, screen washes, and moving objects reinforcing the learning content. However, indiscriminate use of animation in computer-based instruction may hinder its positive effects on learning. Students' selective attention to animation is affected by instructional design method (Reiber, 1991). Only well-designed animation directing a selective attention can be an efficient aid to learning compared to static graphics.

4.1 Animation in Computer Science Education

There have been many literatures on the use of animations in computer science related subjects in the past years. The intuition of computer scientists has led many to believe that animations must provide a learning benefit, but prior experimental studies dating back to the early 90s have provided mixed results.

A study on computer algorithms and data structure examined students learning about the algorithm by reading only a textual explanation and students learning about the algorithm using the text and interacting with an animation of the algorithm (Stasko et al., 1993). Each group had an identical amount of time to study the algorithm, which was followed by a post-test including a variety of questions about the algorithm. The post-test was mostly questions about the procedural, methodological operations of the pairing heap, but it included a few concept-oriented questions as well. There was no significant difference in the two groups' performances on the post-test, but the trend favored the animation group.

Grissom, McNally, and Naps (2003) conducted research to measure the effect of varying levels of student engagement with algorithm visualisation to learn simple sorting algorithms. The three levels of engagement studied were: not seeing any visualisation; viewing visualisation for a short period in the classroom; and interacting directly with the visualisations for an extended period outside of the classroom. Results of their study revealed that algorithm visualisation has a bigger impact on learning when students go beyond merely viewing visualisation and are required to engage in additional activities structured around the visualisation. The researchers also state that it is important that visualisations used by students be consistent with algorithms in their textbooks, or else the visualisations may serve more to confuse them than to aid them.

English and Rainwater (2006) studied the instructional effectiveness of using animations to teach 32 learning objectives in an undergraduate operating systems course. The animations were created using Macromedia FlashTM and were employed as primary pedagogical tools during classroom instruction. In general, descriptions and diagrams served as the basis for reproduction in animated form. The animations were viewed in class by students, as presented as part of the lecture by the instructor at the appropriate point in class when the learning unit was discussed. Pretest scores were obtained by administering the pretest at the beginning of the semester. Posttest scores were acquired by selective inclusion of questions in regular examinations as pertinent to material covered in class. Findings of this study parallels previous research studies which indicate that animations are not effective in conveying information for all learning objectives; i.e. some learning objectives, especially those that are less procedural and more conceptual, are more difficult for students to learn from animation. A closer look at the learning objectives which profited from animation in this study reveals that animations were more beneficial in the sub-topics of processes, memory management and virtual memory. Animations which were designed for these units were generally procedural in structure (English and Rainwater, 2006).

In a study on impact assessment of a microprocessor animation on student learning and motivation (Ferens et al., 2007), the custom animation software was designed to teach second and third year computer engineering students in the microprocessing systems course at the University of Manitoba, Canada. The authors, with over the span of 13 years experience teaching the course, the difficulties and limitations with conventional lectures and visual aids led to the development of custom animation of the course material to provide an additional teaching modality to teach the complex and abstract subject matter more effectively. The animations software consists of the ability to create and/or modify microinstructions, create and/or modify macroinstructions, and animate the execution of instructions (using 'water-flowing through pipes' analogy) by showing address and data transmission juxtaposed against an animated clock. A postunit, mixed method survey was administered to students to reveal cognitive gains and motivational outcomes. Apparently, the use of animation, especially the 'water flowing through pipes' feature was shown to be a powerful component of the animation, and provides an element of visual learning that many students are finding to be critical in their ability to understand. The study also reported on substantial cognitive gains and modest motivational outcomes, reinforcing the animations' effectiveness yet again.

In the use of 3-Dimensional animation, Korakakis et al. (2009) studied the specific types of visualization (3D illustrated, 3D animation and interactive 3D animation) contributed to learning. The results indicated that multimedia applications with interactive 3D animations as well as with 3D animations do in fact increase the interest of students and make the material more appealing to them.
?In summary, it can be stated that animation has mostly enhanced learning rather than detrimental to learning. In this case, the use of animation in computer science subjects have resulted with mixed results in terms of student understanding and performances, but it has mostly enhanced and improved learning. The difficult topics in some computer science subjects were visualised using animations which brought some cognitive gains as well as contributed to some motivational factors to students.

Screen Design: Prototypes

i. Opening Screen

The opening screen is a screen used to display the topic (Memory Management) and the subtopics in the system. All the seven modules have the same opening screen which is the Main Menu page. The students can select the subtopics in memory management. Students can exit from the same page by clicking on the "Quit" icon.

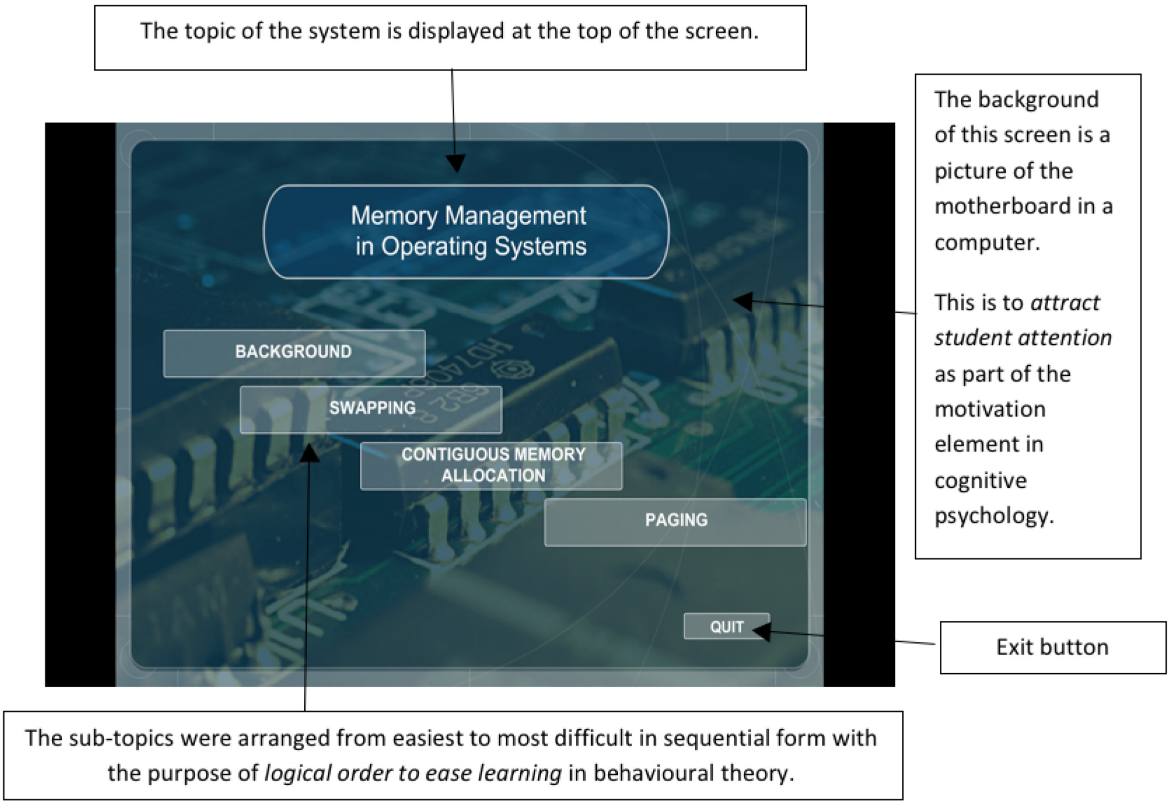


Figure 3: Opening Screen Capture

The colour blue was used as the background colour for OSiMM because of a soothing factor and the colour remains consistent throughout the screens based on the consistency factor in User Interface Design (Ambler, 2000). The background of this screen is a picture of the motherboard in a computer. This is to attract student attention as part of the motivation element in cognitive psychology (Alessi and Trollip, 2001). The sub-topics were arranged from easiest to most difficult in sequential form with the purpose of logical order to ease learning as stated in behavioural theory (Hartley and Davies, 1978).

a) Background Screen

The background screen gives a brief introduction to the concept of memory management. The word 'Background is written at the top left corner and both sides of the screen all throughout the slides. The reason for this is to provide consistency and familiarity to students based on the Cognitive Theory and User Interface Design techniques. The arrow button on the right indicates that the next screen is just a click away. The number of slides is indicated above the 'Menu' button. The button 'Menu' will lead the user back to the opening screen.

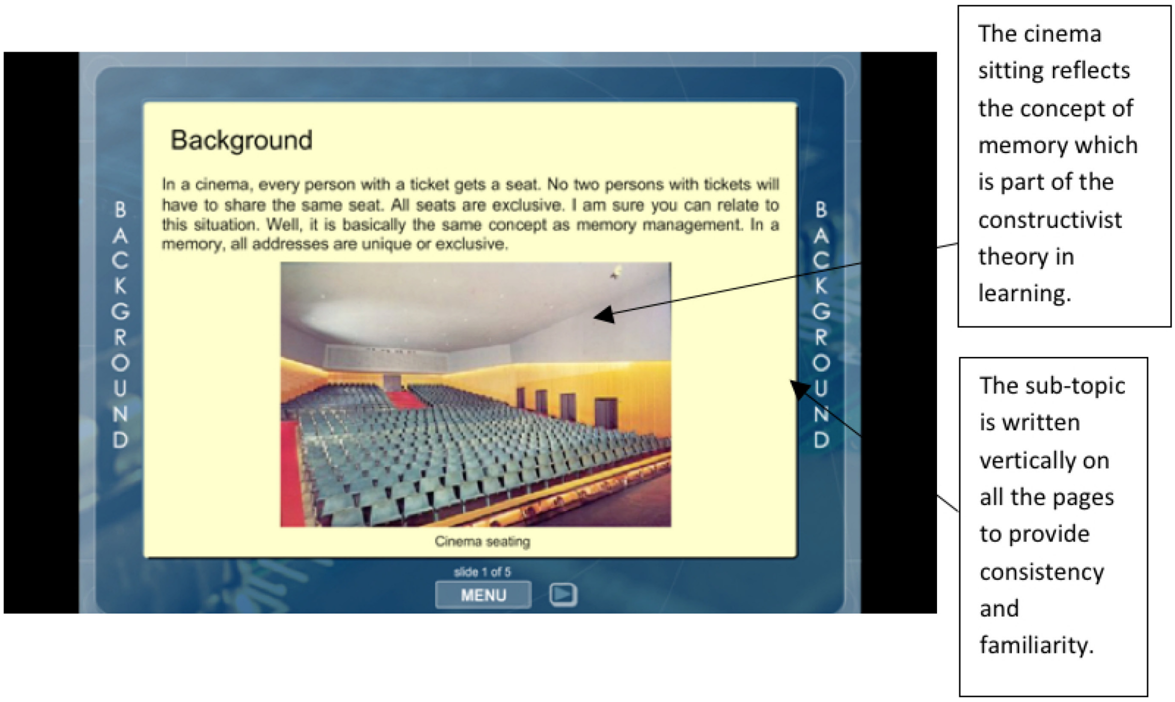


Figure 4: Background Screen

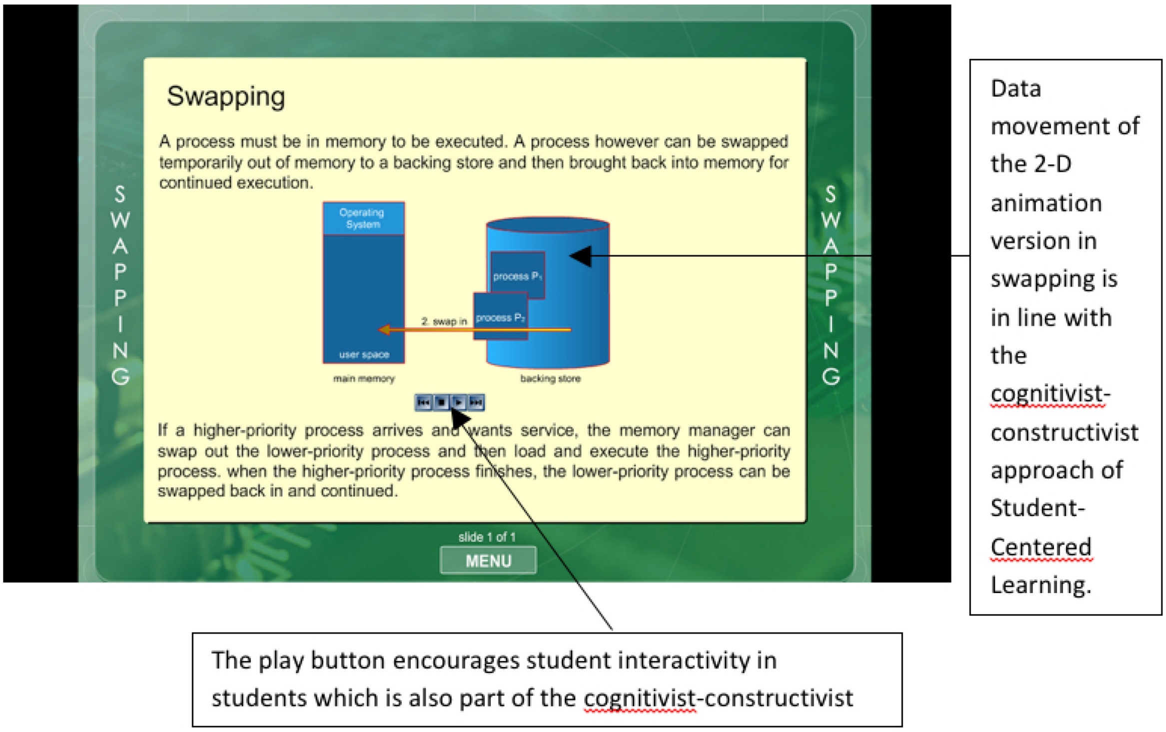


Figure 5: Swapping Screen (2-D Animation)

ii. Swapping (2-D and 3-D versions)

This screen in 2-D version in Figure 5 shows the movement of data from main memory to the backing store in the form of rectangles and cylinder. When the user clicks the play button the process P1 rectangle will swap places with the Process P2 rectangles to show the process of swapping taking place. Once the execution is complete, the Process P2 rectangle will be swapped once again to the backing store. This buttons encourage interactivity in students which is part of the Cognitivist-Constructivist approach to Student Centered Learning. The 2-D animated data movements emphasizes the actions and thinking of learners which is part of the Constructivist approach in learning. Most of the theories discussed earlier in this chapter was implemented in the design and development of OSiMM.

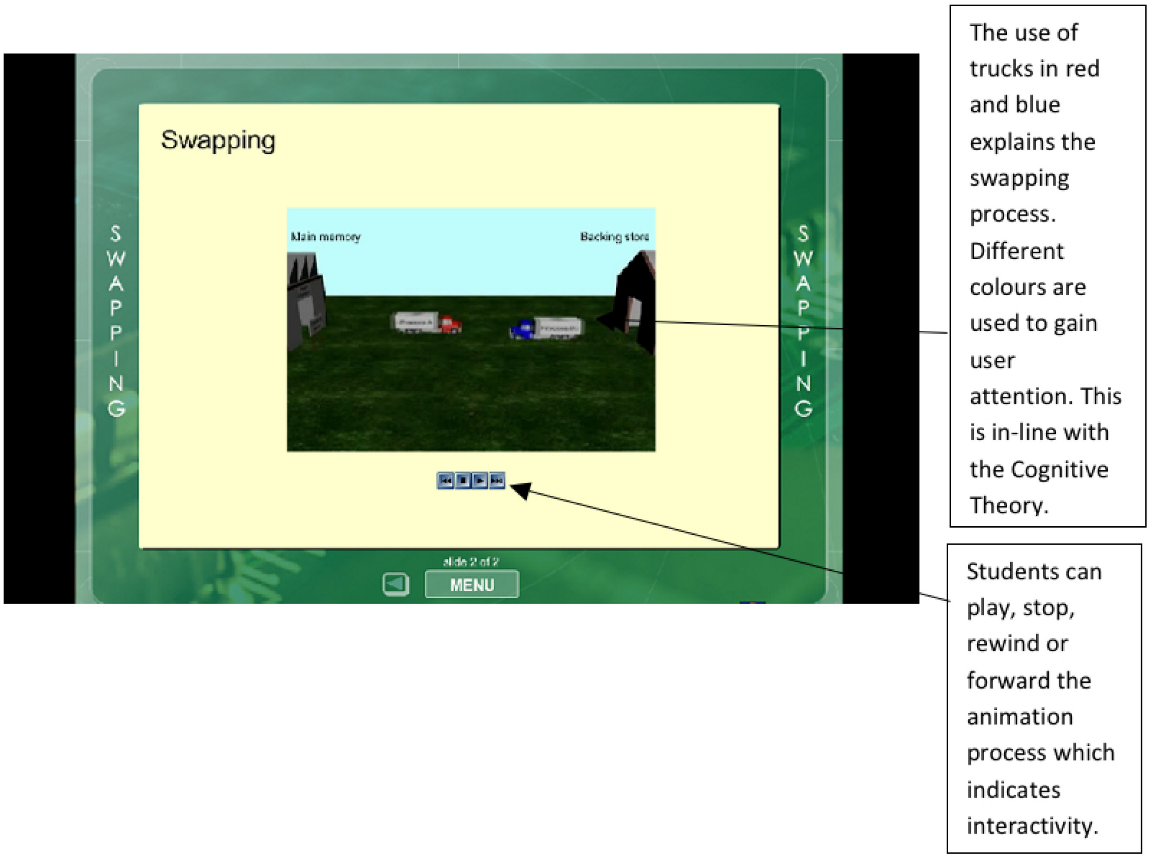


Figure 6: Swapping Screen (3-D Animation)

The screen on Figure 6 shows the swapping process in the form of 3-D animation where the movement of trucks indicate the movement of data. When the play button is clicked, the red truck will swap places with the blue truck. Once the execution process is complete, the trucks will once again switch places. The use of trucks in red and blue shows the use of colour which gains user attention which is part of the Cognitive Theory and the trucks swapping places from the backing store to the main memory indicated the use of constructivism in learning where the theory basically combines new information with existing knowledge and experiences. The buttons indicate interactivity where learners have full access to the learning process.

iii. Contiguous Memory Allocation (2-D and 3-D versions)

This screen capture on Figure 7 and 8 explains on the three methods of memory management that are, first fit, worst fit and best fit. All animation is shown in a 2-D version. The 'static' version has the same graphics and text and the 'animation and voice' module is also the same as shown in the screen capture but the text is eliminated. Figure 11 shows the solution to the problem of fragmentation. The rectangle boxes which has first fit, worst fit and best fit written on it were arranged from right to left but users could click on which ever boxes to get information and see the animation. In Behavioral Theory, learning materials are arranged in logical order to ease students' learning. Nevertheless, students have a choice to view which ever information they wanted. User has a freedom of choice.

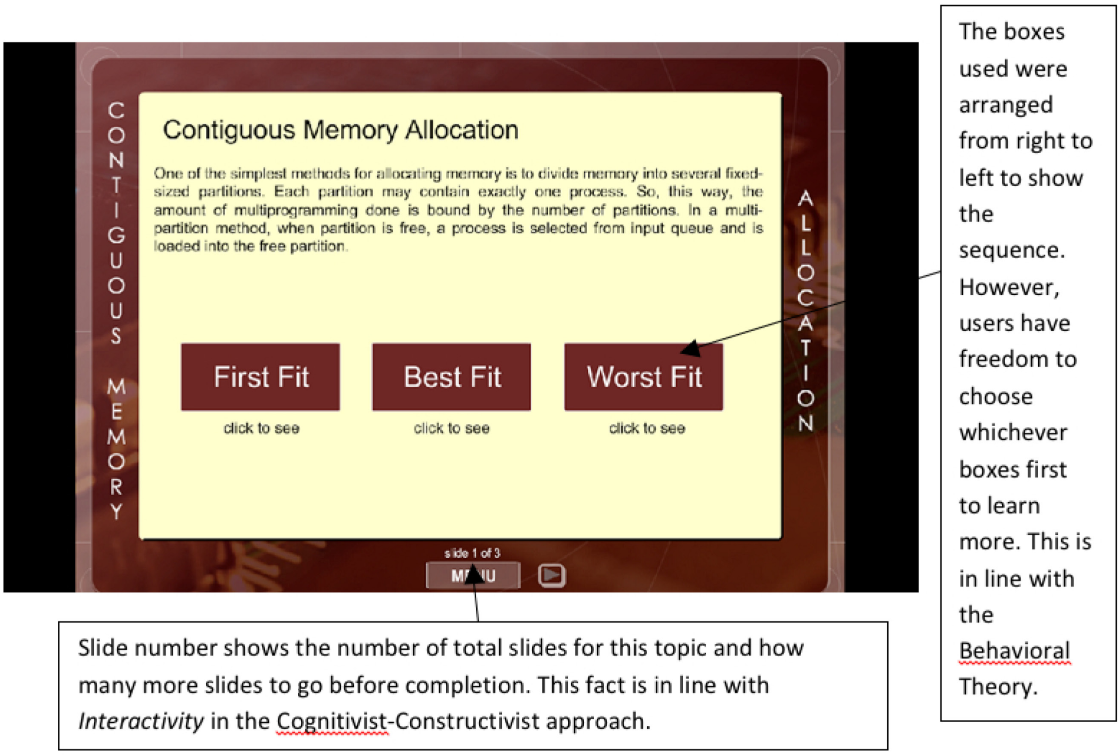
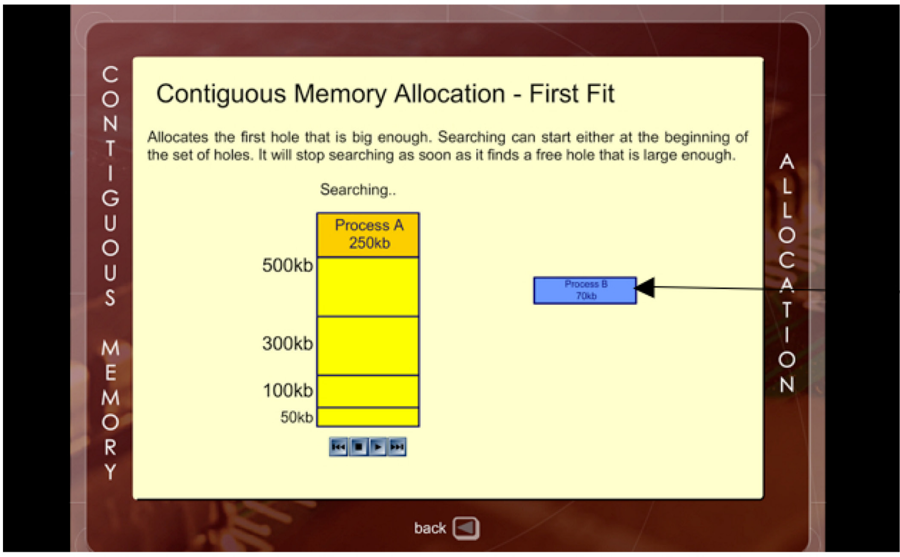


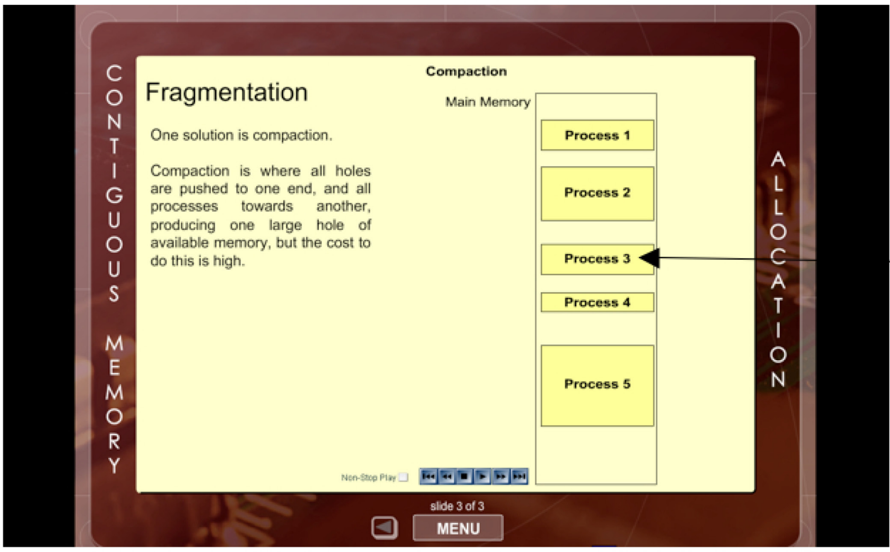
Figure 7: Contiguous Memory Allocation Screen (2-D Animation)

Figure 7 shows the process of First Fit, where the new process searches for a place to execute and in order to do that it will need to find the first location that fits the space. Students' process new information in their memory and this is an integral part of the Cognitive Theory of learning. The number of slides in one sub-topic is displayed. This informs the students how many slides there are for that particular topic and how many more slides to go before completion. The most important goal for adding interactivity is to provide the learner with the choice to decide where to explore first within the application at his or her own pace. Interactivity is an integral part of Student Centered Learning in Cognitivist-Constructivist approach.



The blue box indicates a process with 70 kb and it will be inserted into the yellow frame when it finds the first box that fits. This concept follows the information processing approach in Cognitive Theory.

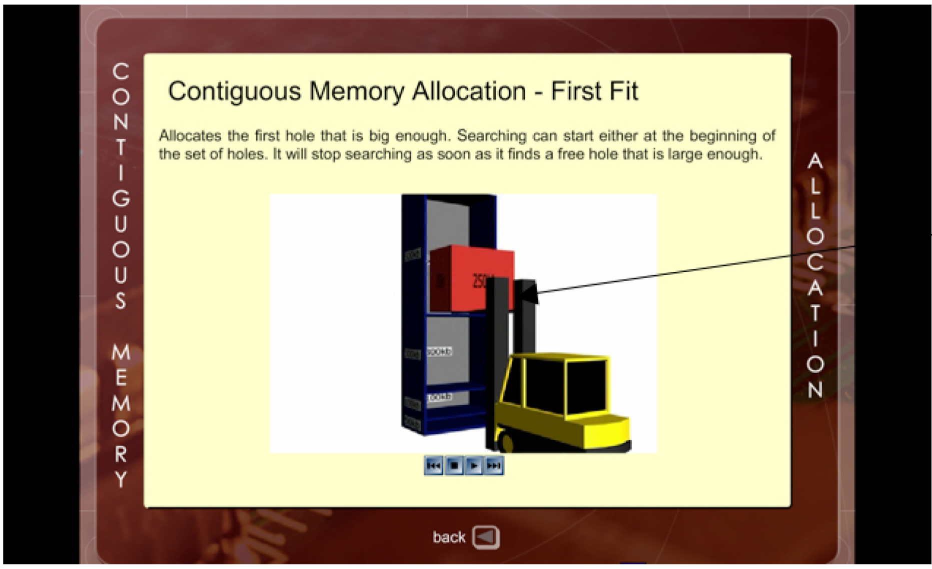
Figure 8: Contiguous Memory Allocation Screen - First Fit(2-D Animation)



Fragmentation process will show all the process boxes combining together to save space. The animation will compress all the 5 yellow boxes. This supports purposeful learning activity in Constructivism.

Figure 9: Fragmentation Screen(2-D Animation)

The 2-D animated version for Fragmentation in Figure 9 used the boxes as symbol for processes and the compaction process is shown with animation where all the 5 boxes come together to form compaction. This process supports purposeful learning where the learner learns something new about the Fragmentation process by just observing the animation perform the compaction process. Just observing the process alone provides purposeful learning if the message was delivered well. This is part of the Constructivist Theory. For the 3-Dimension animation version the use of a forklift for carrying data chunks into allocated slots was implemented. The forklift was used to carry data in chunks to the shelves where the space is large enough for the data to fit in. For First Fit method, the forklift would shelve the data in the first hole which is large enough to fit the data. For the Best Fit method, the forklift would scan all the shelves to see the sizes of the shelves and then decide which data is most suitable for which shelve according to the shelve size. This will lessen the fragmentation involved, which are the empty spaces available due for memory allocation process.



The use of forklift and shelves to arrange data processes in First Fit relates to real world situation and in accordance to Anchored Instruction in Situated Learning.

Figure 10: Contiguous Memory Allocation Screen - (3-D Animation)

The concept of forklift and shelves was inspired by the real world situation in a warehouse where forklifts are used to carry items to specific shelves for storage. Using purposeful, real or authentic learning activities and encouraging learners to accept and reflect on the complexity of the real world is a part of the Anchored Instruction in Situated Learning for Constructivist Theory.

The fragmentation process in Figure 11 shows an animated version of compaction, that is, the solution to the fragmentation problem. The graphic shows that a strong force from below would compress all the lose data with spaces in between and data is pushed to one end at the top. This idea was inspired by the use of force to flatten concrete at the construction side. Learners can reflect on the complexity of the real world which is a part of the Anchored Instruction in Situated Learning for Constructivist Theory.

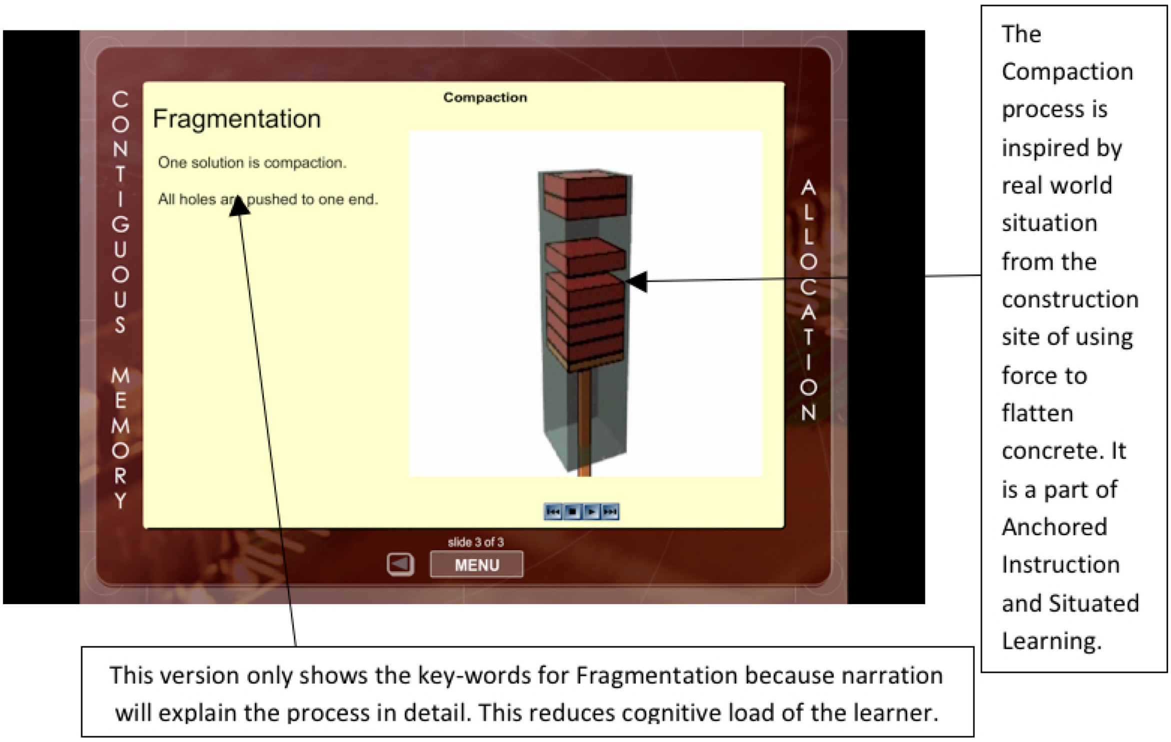


Figure 11: Fragmentation Screen - (3-D animation)

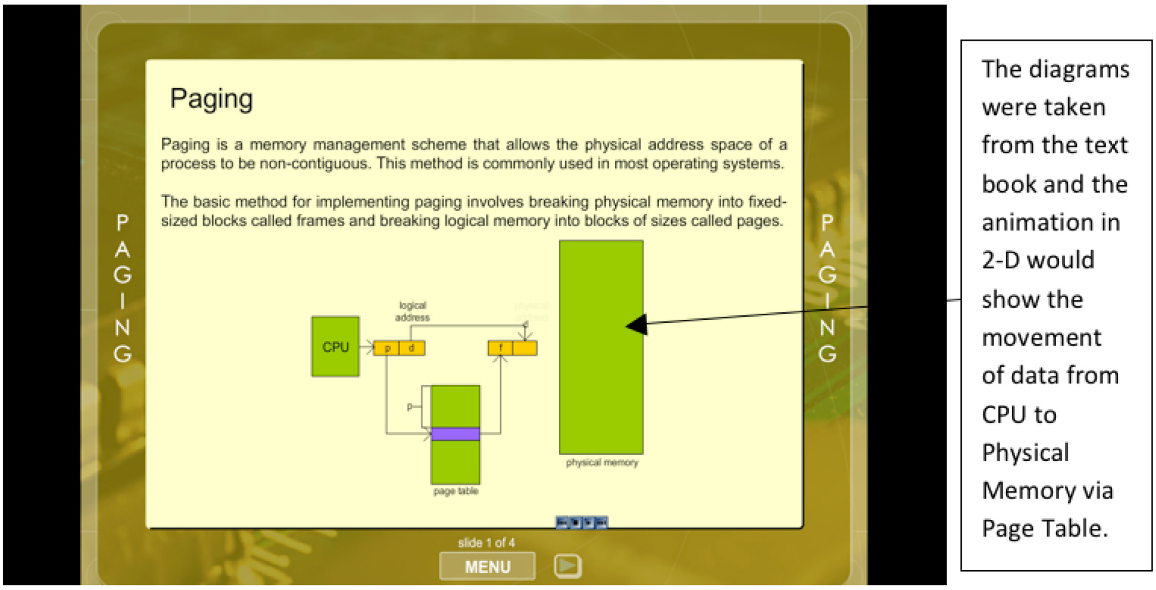


Figure 12: Paging Screen - (2-D Animation)

iv. Paging - (2-D and 3-D animated version)

The screen on Figure 13 and 14 shows the paging process in memory management. The sub-topic is one of the difficult concepts in this chapter. Figure 13 shows the diagram of the Paging process which was adapted from the Operating Systems Concept text book (Silberschatz et al., 2006).The animation shows the movement of data from CPU to Physical Memory via Page Table. Calculation is needed to obtain the physical memory allocation and the example is shown on Figure 13. The colour red is used to show the movement of data from Logical Memory to Physical Memory to gain user attention.

The 3-D version of paging was designed using the same concept, however, a metaphor of heavy equipment was adapted in this version. For the main concept of paging, an excavator was used to show how the data was moved from logical to physical memory. This indicates situated learning in Constructivism where the learner combines new knowledge and experiences with existing ones. Figure 14 shows the process.

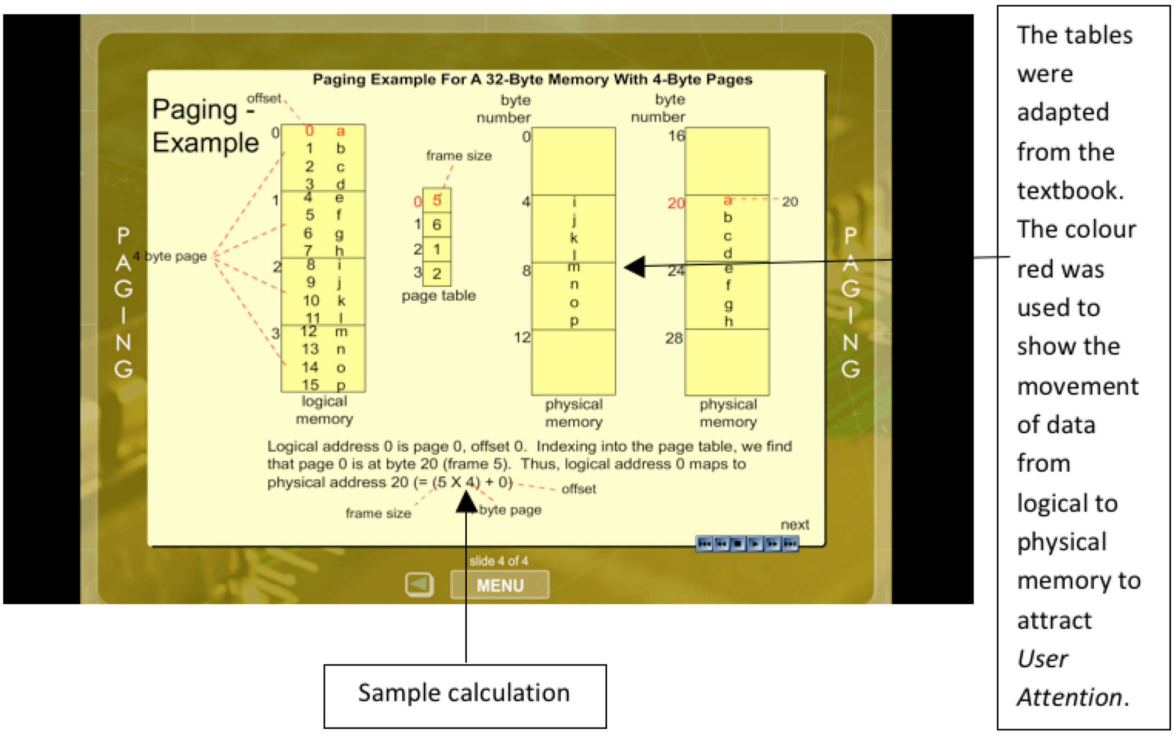


Figure 13: Paging Screen - Example (2-D)

Figure 14: Paging Screen - (3-D animation)

Conclusion and Future Research

This paper had reported on the various learning theories that were used in the development of a learning application for memory management, named OSIMM. Mayer's cognitive theory of multimedia learning was applied as a guideline in the development process, to achieve a learner-centered approach in the application, and the prototypes in two versions (2-D and 3-D animation) were developed. This design and prototype could be a guideline to future instructional designers, web developers and e-learning specialist if they want to develop courseware for a computer science or engineering subjects.

The next step in this research is to compare the effectiveness of the 2-D and 3-D animated versions of OSIMM by conducting a series of experiments on users. The measure of effectiveness will be determined by giving the students a test on recall and transfer knowledge. This research would further be refined by conducting a series of experiments with two sets of users, low prior knowledge and high prior knowledge. This would be achieved by asking the users to fill in a prior knowledge survey.

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