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CONCEPT MAP IMPLEMENTATION STRATEGIES IN TEACHING AND LEARNING: A CASE STUDY OF BIOLOGY SUBJECT

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ABSTRACT

Biology is a remarkably complex subject. It takes imagining, memorising and remembering facts, concepts, and processes. Students perceive Biology as a challenging and an unexciting subject. Apart from that, it is difficult to develop skills in visualisation and imagination while trying to grow the students' reason and judgment. A comprehensive method to facilitate memorisation is required to tackle this issue. One of the approaches is by implementing a concept map (CM) in multimedia courseware as the teaching module. CM represents knowledge and facts in a visual and graphical form. With a proper design and development, CM helps assist students in their learning process. This paper describes the design and development process of multimedia teaching and learning prototype that applies CM for teaching biology. The objectives of this research are to propose a CM approach as well as to evaluate its effectiveness from end users' point of view, particularly biology subjects taught in secondary school Form Five syllabus. A standard model in multimedia application development known as ADDIE is applied in this research. Two experiments were conducted to evaluate the prototype application in which effectiveness and usability parameters are being measured. The result demonstrates 86% of the respondents perceived the tools as relatively useful, and both the pre-test and post-test revealed steady improvement in learning abilities. Therefore, this prototype is developed to better aid the process of teaching and learning of Biology.

Keywords: concept map, biology subject, hierarchy, teaching and learning, knowledge representation

1. Introduction

An interactive multimedia application combines several elements such as audio, video, text, image, graphics, and animation to make teaching and learning more effective and exciting. In general, most of the contents are provided through object visualisation. Visualisation can be created based on non-visual data, which will produce meaningful, readable, and recognisable graphics, images, or other kinds of representation. Apart from 2-dimensional representation, there are some other types of visualisation such as 3-dimensional (3D) illustration, 3D animation, and interactive animation. To make it interactive, the representation of information must allow quick navigation and the access must be in a natural manner (Kosara, 2008).

One of the visualisation techniques that can be used to visualise a link, or a pipeline of information is a concept map (CM). CM has been used widely in conventional teaching and learning methods, due to the reason that it is compelling in forming and demonstrating knowledge. According to Friedland, Hürst and Knipping, (2007), CM is usually bounded in circles or boxes, and relationships among concepts are specified by a connecting line linking

the two concepts. The educational multimedia app can make learning easier, convenient, and effective. CM allows students to think holistically as its visual mechanism represents a set of ideas by linking related concepts and explaining the connections. In other words, it helps students in understanding the relationships between key points effectively.

CM is also a knowledge visualisation tool that can be easily understood (Cañas et al., 2005). Knowledge elicitation methodologies and format notation are the standard methods used by the knowledge engineering and representation communities, particularly from artificial intelligence viewpoints. However, focusing specifically on knowledge representation, far too little attention has been paid to visualisation. Therefore, this project proposes designing and implementing CM on teaching and learning modules that incorporate a 2D interactive graphical animation in an interactive multimedia environment. The developed module is anticipated to facilitate students to organise, represent, and understand knowledge. This study performs a case study of a biology subject taught in Form Five secondary school students.

2. Problem Statement

Biology has been a significant subject taught in secondary school in Malaysia as part of science stream packages, namely in form four and five, and it will be tested in a significant examination known as *Sijil Pelajaran Malaysia* (SPM). Teaching and learning biology subjects can be considered challenging for both teachers and students. According to Nurse (2016), biology is the most crucial area of study as it introduces to students all fundamental parts of human anatomy. However, biology is a complex subject as it is hard to teach students regarding facts; from the tiniest algae to the very great elephant, life has a particular wonder about it (Bailey, 2019). It is a challenging subject that students need to understand instead of memorising the facts (Atilla, 2012). Despite the subject's importance, students' performance was below the mean performance of all the matriculation colleges throughout the country (Malaysia) for several semesters in the past three years (Yeoh & Ierardi, 2015).

Previous research papers show that graphic representation, scientific visualisation, and data visualisation enhance attention among students (Chen, Deng, Zhang, & Xiao, 2009). It is also found that using CM as a visualisation tool helps students in the science field by stimulating knowledge sharing and understanding new things. Therefore, this project applies to CM which includes a visualisation tool to promote active learning and interactivity through multimedia elements such as animations, sounds, graphics, and texts.

3. Research Questions and Objectives

Specifically, this study seeks to address the following questions: (i) how effective is the use of CM in delivering teaching and learning content? (ii) how will the students perceive the effectiveness of the content delivery, and (iii) to what extent does this CM prototype help deliver the content successfully? This study, therefore, sets out to assess and provide solutions to these questions. The objectives of this study are (i) to design and develop a prototype module for teaching and learning Biology for secondary students that implement a CM technique, (ii) to evaluate the usability, and (iii) effectiveness of the application.

4. Scope of Research

This prototype application is designed for form five students in secondary schools who take the '*Sijil Pelajaran Malaysia'* (SPM) examination in Malaysia. This prototype takes Chapter 4 (Human Being) specifically on the subtopic "Growth and Reproduction" as the CM content.

This prototype is tested on the selected users. The primary purpose is to evaluate the effectiveness and usability of the prototype courseware apps. The experiment focuses on whether the new teaching and learning mechanism is practical and usable to its target users. It is carried out during and after implementing the multimedia prototype application, including pre-testing, post-testing, questionnaire, and observation. The prototype app was developed using Java and Adobe Flash. All objects were designed and integrated as multimedia elements using Adobe Photoshop, Adobe Illustrator and Sony Sound Forge. This standalone prototype courseware application was tested on Windows operating system to minimise mobile data required during its execution.

5. Literature Review

In recent years, academics and educators have been using software mapping tools for several education-related resolutions. Typically, the tools are used to help convey critical and analytical abilities to learners, empower learners to see relationships between concepts, and as an assessment method (Davies, 2011). The following section presents the literature on the use of CM and a few projects related to the CM.

5.1 Concept map as a tool in teaching and learning

CM is known as the visual linking concept with propositions. It includes the construction of concepts enclosed in shapes and propositions of relationships between the concepts indicated by lining words (Koc, 2012). Computer application and technology improved the use of CM where it simplifies and alters various multimedia elements such as colours, shapes, figures, hyperlinks, audio and video (Chang, Sung & Chen, 2001). Prior research demonstrated that constructing a CM with a computer is perceived to be appealing and more effortless than writing on the papers (Koc, 2012). To represent knowledge, CM is used in many ways to evaluate learners' performance and diagnose misunderstandings as well as to design and develop a project, learning tools, and decision making (Ruiz-Primo, Schultz & Shavelson, 1997). Jonassen (1996) mentioned that CM is a constructive-based mindtool; he quoted, "a way of using a computer application program to engage learners in practical, higher-order, and critical thinking about the subjects they are learning". Mind maps improve learner's capabilities in certain critical parts, including the ability to draw reasonable inferences from observations, the ability to synthesise and integrate information and ideas, and the ability to learn concepts and theories in the subject area (Angelo & Cross, 1993).

There are four major groups of mind maps or CM differentiated by their format for representing information. The maps are spider, hierarchy, flowchart, systems, picture landscape CM, and others. The hierarchy CM is the simplest and easiest that would help students understand the subject better. It presents information in descending order of significance; the essential information is located on the uppermost. Distinguishing aspects decide the location of the data.

Hierarchy CM allows students to understand the relationships between concepts and hence understand those concepts themselves including the domain to which they belong (Davies, 2011). In the context of teaching and learning Biology, it provides a new environment for learners which are essential in their cognitive improvement in stimulating the learning progression. It also allows them to construct a physical and comprehensive understanding.

CM is operational and practical as it creates details in a visual procedure. A conservative methodology is a paper-based and neutral-based methodology. On the contrary, a CM can visualise based on the actual mechanism with multimedia elements. Interestingly, the biology

subject attracts students with more attractive features that will eventually help them enhance their understanding of the subject. For example, in learning exercises that comprise questions and answers, a CM allows signifying questions and answers. Besides, it is also possible and helpful to be used in tests or examinations, revision, information assessment and others.

5.2 Related research

Few previous research papers commonly reviewed the application of CM combined with case-based reasoning to elaborate an intelligent teaching-learning system. Only a few previous research papers combine CM with case-based reasoning to heighten intelligent teaching-learning systems. Espinosa, Sanchez, Valdivia and Perez (2007) presented a new approach to elaborate this system where concept diagrams, concepts map and artificial intelligence are combined using the case-based reasoning as a theoretical framework for the student model. This model has been implemented in the computational system HESEI, which has also been successfully applied in the teaching-learning process. The model with its corresponding CM with a particular feature can capture students' cognitive and affective states, which will then help the student navigate through the system.

CM is a technique that arranges knowledge in the form of connected nodes. Salleh and Ismail (2013) assessed a CM approach in delivering History subjects taught in secondary school to test whether it can improve the students' understanding and cognitive development. Courseware with a CM feature has been developed to complement the textbook used for this subject. An experiment assessment of the courseware was conducted among twenty students in a chosen school. Students must fill in a form to assess the effectiveness of the CM instructional delivery and usability of the design interface. In particular, the study observed the effectiveness of a simulated learning experience, interface design as well as the technical aspects of the courseware. The findings from the study suggested that in general, an implementation of CM has been practical and useful. The study's outcome concluded that CM is one of the promising methods that can be effectively used to teach History in secondary students.

6. Methodology

For this study, a standard methodology used in multimedia application development called ADDIE was applied. This section will explain the ADDIE model in detail with logical and physical interface design supported with a structured chart. There are 4 primary stages involved in this study. The first stage covers its theoretical and feasibility studies of CM and Biology subjects. The characteristics of the target users and other related requirements were identified.

The second stage is design, which involves lesson content design that follows specific teaching and learning strategies. The hierarchy structure of the CM technique has been tailored to align with the design. The visualisation of lesson content and objects design requirements have been specified based on focus group discussion and interviews with 3 subject matter experts, namely teachers who have been teaching the subjects for 3 to 5 years. The design rules set as the main structure include the general concepts presented at the top and specific concepts at the bottom. It looks like a big to small rule as the root node represents the main topic. The design applied is based on the improved method by Ahlberg (2008).

Table 1: Improved design in the biology courseware

No	Ahlberg (2008) proposed method	CM design implemented in Biology Courseware
i	Construct the main concept as a pipeline of thinking and the content always within the frames.	Divide the viewing canvas into two sections. One section shows the pipeline of the whole content. Another area focuses on a topic selected by the user.
ii	Terms and words to be correctly labelled. There is no accurate boundary on how many words should be put in a concept tag.	Precise terms have been used
ii	Emphasising an effective plan, the links amongst concepts require points to display in which path the connection from one concept to another is to be read.	Represent as components label
iii	The expressions connected to links must precisely prompt the rationale of the person.	Same implementation
iv	Connect all elements - pictures, videos, sounds in the map as a whole.	Same implementation

In the third stage, the design framework is implemented which involves the preparation of all multimedia objects and intense programming by using authoring tools.

Finally, the fourth stage is the evaluation. It comprises a series of experiment exercises. The formative and summative test has been conducted twice in one of the previous exercises (Salleh *et al.*, 2017). This research also looks at how sustainable elements can strengthen the research outcome, so another exercise has been carried out to measure the effectiveness and usability of the prototype among current students.

6.1 Logical and physical design

The application prototype consists of two modules which include teaching and learning. Users will go through teaching processes followed by a learning module that comprises reviews of exercises and quizzes. The interactive interface of the quizzes allows finger touch, and the questions are divided into (i) multiple-choice questions, and (ii) drag and drop format. The courseware interface and navigation were designed to be user-friendly to give users the freedom to control their navigation fully. The process flow of the courseware is shown in the following Figure 1.

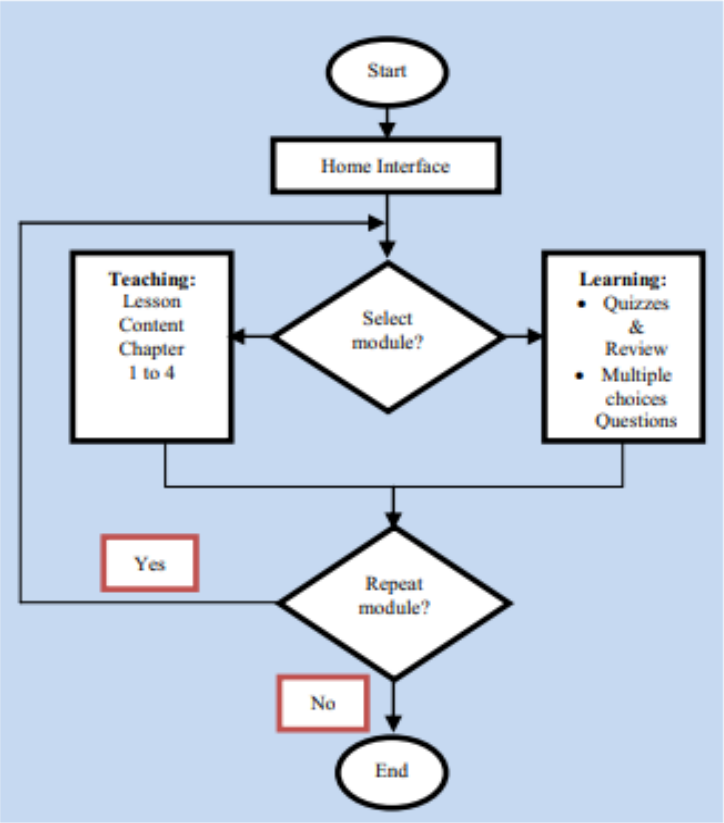
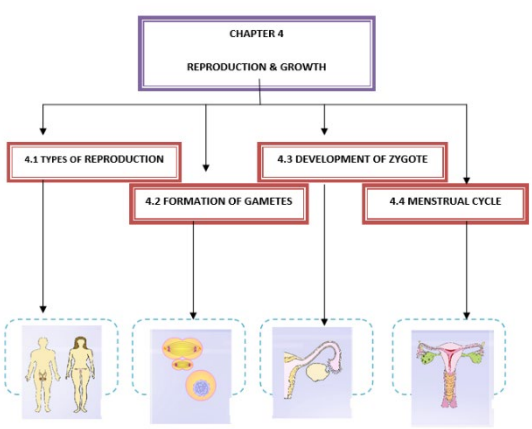
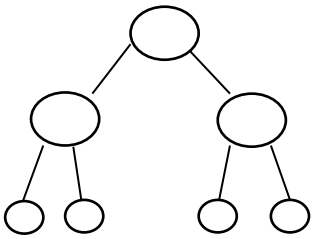
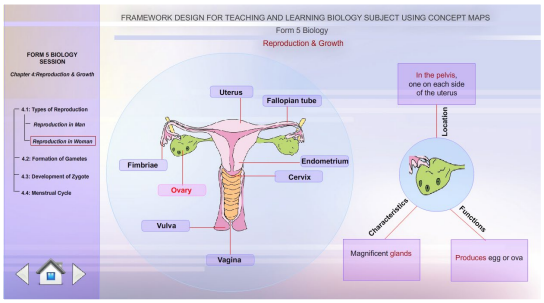
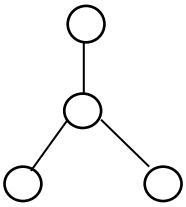
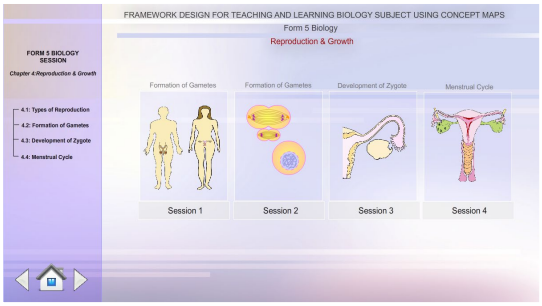
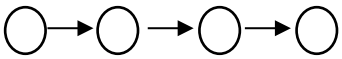


Figure 1: Process flow in the courseware (Salleh *et al*., 2017)

The following figure illustrates the screenshots of the courseware prototype physical design. Figure 2 and 3 show its teaching section and learning section, respectively. Each of the lesson content in the prototype courseware applies the CM nodes arrangement and structure that will facilitate cognitive loads and students' understanding of the subject matters.

Table 2: Logical design for teaching section

Teaching Section	
Physical Design	CM Logical Design
	Hierarchy Design 
	Spider Design 
	Sequencing Nodes Design 

Hierarchy and spider map designs have been used comprehensively in the courseware. The nodes have been represented in the form of relevant images that correspond to the topic. The courseware is designed based on simplification, representation and arrangement of the nodes. The presentation of images and the structure of the nodes affect viewers' cognitive flows. While

simplification focuses only on essential parts of the subject matter, the proper arrangement of the nodes also contributes to it.

Table 3: Logical design for learning section

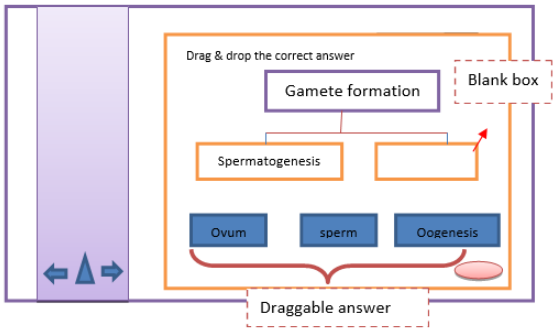
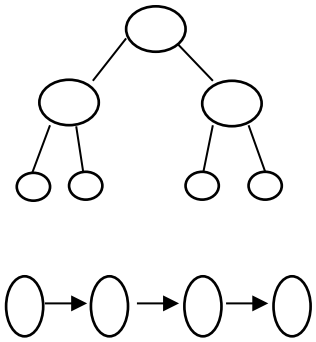
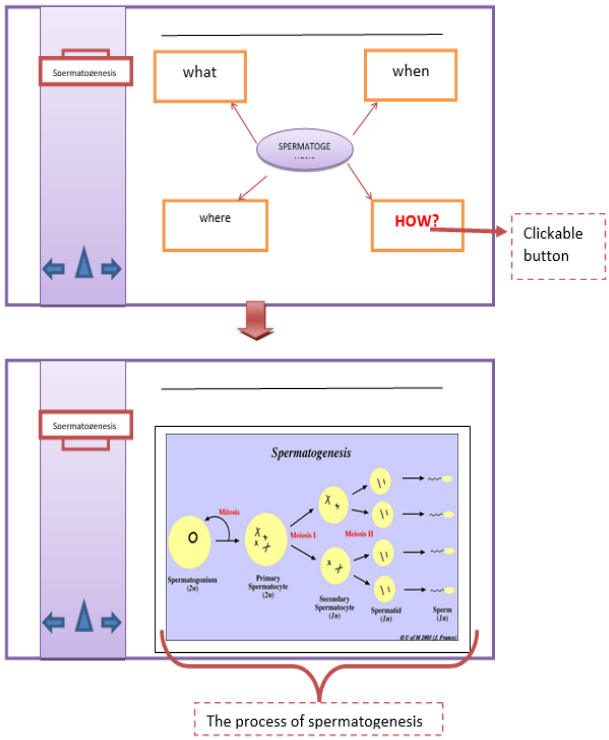
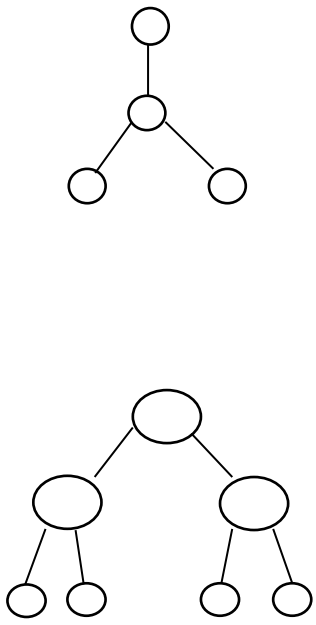
<table>
<tr><td colspan="2">Learning Section</td></tr>
<tr><td>Physical Design</td><td>CM Logical Design</td></tr>
<tr><td> 
</td><td>  </td></tr>
<tr><td> 
</td><td>  </td></tr>
</table>

Table 3, shows the application of three CMs to explain the male reproductive structure. A hierarchy map is used to indicate current topics and its corresponding links to other contents on this page. Two spider maps are used to explain and visualise the reproduction structure. All objects in the page are clickable, animated, and supported with narrations and texts. Specifically, the general knowledge is placed at the top and the specific knowledge is placed at the bottom within its context. In both structures, the horizontal axis expresses a hierarchical framework for the concepts. In general, inclusive concepts are found at the highest levels, with progressively more specific, less inclusive concepts are arranged below them.

Figure 2 shows the screenshots of the learning module, which comprises review and quizzes. Users are required to select the answer and drag and drop objects. Apart from object dragging and selection, the module also comprises clickable multiple-choice questions. The questions are arranged using a hierarchy format. Users can freely answer the question repetitively until they are satisfied with their scores.

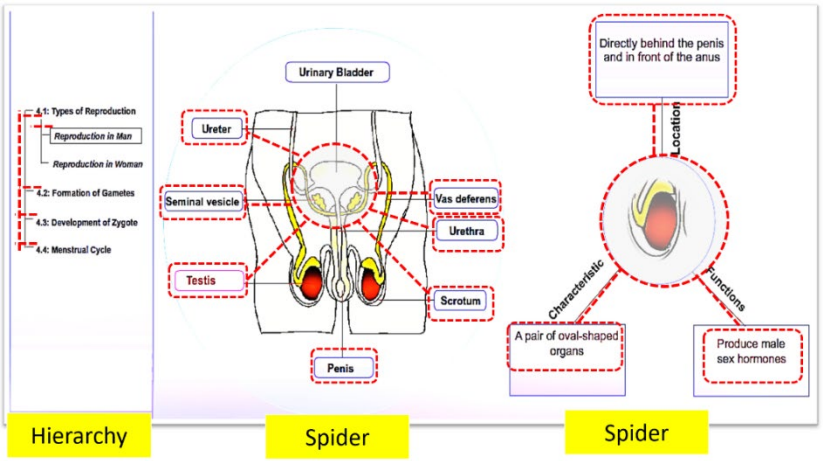


Figure 2. Screenshot of male reproduction structure

7. Results And Discussion

Salleh *et al.*, (2017) performed the usability and effectiveness of this biology CM app in their previous study. In that study, 50 students who were taking biology from the 2016 cohort participated. Respondents from this cohort were randomly assigned into two groups, i.e., control and experimental. Students in the control group learned biology in the traditional way, while the experimental group learned biology using the CM app. Both groups of respondents had to take the pre-test and post-test of a paper-based quiz. The results of the experiments suggested that there was a positive impact on students' biology test scores in which the average score of the pretest was 66.76%, and the average score of post-test was 85.56%.

Therefore, this research discusses the same experiment with another group of students from the 2019 cohort. Figure 3 illustrates the experimental procedures. This experiment is reconducted to verify the usability and effectiveness of the biology CM app. 17 students were involved in the second set of experiments - 7 of them were placed in the control group while others were in the experimental group. At the beginning of the experiment or so-called pre-test mode, both groups of respondents were required to answer a paper-based quiz (question Set A)

and their scores were recorded. Respondents from the control group were required to study the biology subject in the conventional way from the textbook. At the same time, the experimental group was given the CM Biology app to explore and learn the biology topic. Then, both groups of respondents were given question Set B to answer. Scores from the second quiz (question set B) were recorded.

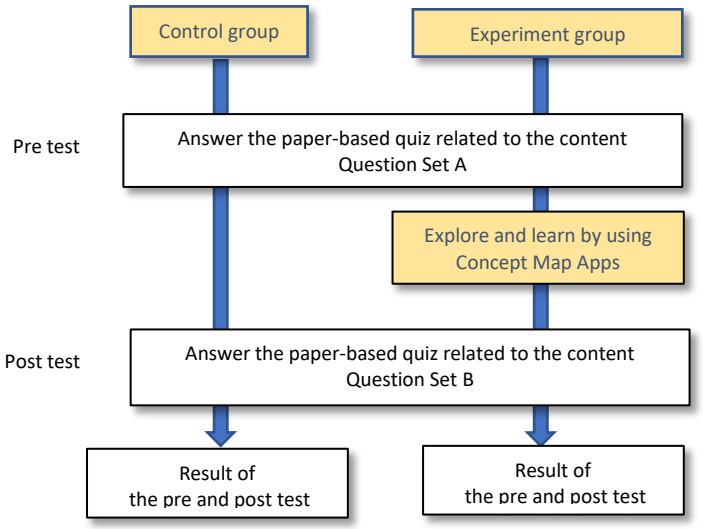


Figure 3: Illustration of the experimental procedure

Table 4 presents the experimental group's results from 2016 and 2019 cohorts. The scores in 2019 showed an increase from the 2016 cohort. It can be justified that the increase in score resulted from the maturity of the CM app and teacher's expertise in using the app in teaching process, thus increasing students' performance.

Table 4: Average test scores

Group	**Average score (%)**	
	Pre-Test	**Post - Test**
Respondents from 2016 cohort	66.76	85.56
Respondents from 2019 cohort	70.1	86.70

The usability of the courseware prototype was also assessed, which included the design of the interface, sound, interactivity, animation, content and general perception. The responses to these questions were tallied on a 5-point Likert scale, with Absolutely Highly Agree = 5, Agree = 4, Neutral = 3, Disagree = 2, and Strongly Disagree = 1. Figure 5 illustrates the summary of the findings.

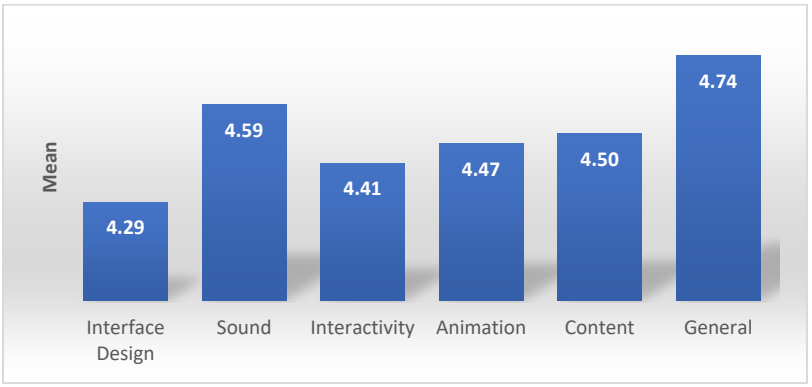


Figure 4: Students' perception towards courseware usability

The result showed that all criteria measured have a mean value above 4.0, indicated as significantly agree and strongly agree. It is apparent from this result that students perceived the CM prototype positively. Hence, we characterised the design concept in the courseware as our findings. A summary of the respondents' perceptions on the value of understanding, attractiveness, difficulty, and others is shown in Figure 6. The negation "difficulty" criteria has a mean value below 4.0, which verifies the consistency of users' perception. Overall, the result indicated that all criteria were agreed upon as the mean values were above 4.0 (Hodge & Gillespie, 2003).

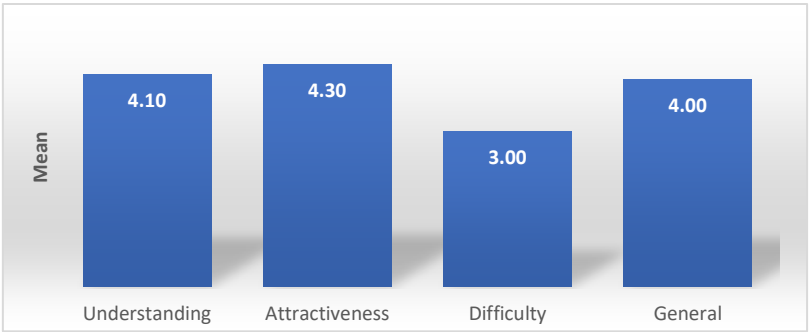


Figure 5: Perception towards the courseware prototype

This prototype application integrates multimedia elements in its teaching and learning module, optimising animation, visual, text, audio, and graphics. Based on the result, it is proven that the CM approach implemented in this courseware is perceived as usable and acceptable in students' learning. The results of the usability perception were also promising.

8. Conclusion

This paper presents the design of a courseware prototype that extensively applies many forms of hierarchical and spider CMs. Results of the experiment indicate that the design facilitates students to learn and visualise topics of biology subjects effectively. In future study, this experiment is hoped to be extended to a wider group of respondents and the relationship between parameters will be analysed beyond effectiveness and usability.

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