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**The effects of mind-mapping technique in engineering mathematics**


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The Effects of Mind-Mapping Technique in Engineering Mathematics

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Abstract—This research aimed at finding out the effects of using mind mapping technique on academic achievement and cognitive load in Engineering Mathematics. Apart from that, the relationship between the cognitive load and academic achievement was also investigated. A total of 28 students were assigned into the experimental group (N=14) and control group (N=14). Academic achievement was measured using post test and cognitive load was gauged using NASA-TLX questionnaire. The present research has proven that using mind map in teaching and learning will significantly improve students’ achievement and reduce the cognitive load in Engineering Mathematics. In addition, it has been found that cognitive load is negatively correlated with academic achievement. In conclusion, mind mapping technique can be considered as an effective learning tool in Engineering Mathematics.

Keywords—mind-map, cognitive load, engineering mathematics, academic achievement

I. INTRODUCTION

In school, students are exposed to the mathematical problems solving of various complexity levels ranging from easy to difficult. Thus, educators' teaching method are important to ensure effective delivery of the concept of mathematical knowledge to the students. Educators can opt for various methods to impart the knowledge during the teaching and learning process and effective teaching can give a significant impact to the learning process. Idris states that a few necessities are needed to create an effective teaching, such as in-depth understanding to the teaching process, students' trait and stage of development, and motivational factors [1]. Besides, Sulaiman [2] also mentions that effective teaching are those that consider psychological and professional aspects.

Even so, to ensure good achievement of the students, educators need to be alert to the cognitive load experienced by each student during the learning process. According to Clark, Nguyen and Sweller [3], cognitive load is the burden experienced by students during the learning phase and students are unable to process the extra information provided the cognitive load exceeds the limit. A human brain can only process 7±2 items at a given time [4] and if the cognitive load is exceeded, students will be unable to absorb the learning contents. Clark et al mentioned that cognitive overload is caused by certain teaching methods that are ill-planned [3]. Thus, to minimize the cognitive overload, a strategic teaching plan must be mapped out.

Students tend to experience cognitive overload when they are dealing with complex learning contents [5,6], such as Engineering Mathematics. If this occurs, students will not have sufficient cognitive resources to process the to-be-learnt information, and thereby failing to construct meaningful schema. To put it simply, it will hinder learning and academic performance.

To overcome this problem, some researchers (e.g., [7,8]) suggested that mind-mapping technique can be used to improve the students' achievement. Thus, this research was conducted to determine whether mind map can be used to improve students' performance in Engineering Mathematics. Apart from that, the present studies also aimed at investigating the effects of mind map on cognitive load because academic performance is greatly influenced by cognitive load [9]. Lastly, the correlation between cognitive load and academic achievement was also explored.

II. METHODOLOGY

A. Sampling

A total of 28 students from various engineering faculties who had registered for Engineering Mathematics Course were invited to participate in this research. The participating students were randomly assigned into experimental (N=14) and control groups (N=14).

B. Instrument

Three instrument were used in this research, namely, pretest, post test, and a standardized questionnaire (NASA-TLX).
Pre test was used to determine the prior knowledge of the participating students in order to ensure the students in both groups had similar level of prior knowledge.

Post test was utilised to measure the academic achievement in Engineering Mathematics.

NASA-TLX was used to identify the level of mental effort invested by the students during the experiment. Mental effort was to be used to reflect the cognitive load induced during the teaching and learning process.

III. RESULTS

A. Pretest

The pre-test was conducted to ensure the experimental and control groups are comparable in terms of prior knowledge. Table 1 shows that the mean score for pre-test for control group is 57.50 (SD= 24.38) while the mean score for pre-test for treatment group is 62.86 (SD=17.18). The t-test result revealed that there was no significant different between the groups in terms of prior knowledge (t(26)=0.67, p>0.05).

Table 1: Test scores for control group and treatment group

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Score</td>
<td>Control</td>
<td>57.50</td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>62.86</td>
</tr>
<tr>
<td>Post-test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Score</td>
<td>Control</td>
<td>48.64</td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>75.14</td>
</tr>
</tbody>
</table>

B. Post test: Students’ Achievement

The mean of post test score for control group is 48.64 (SD= 25.79) while treatment group yields 75.14 (SD= 12.13). See Table 1. T-test was performed to find out whether the scores differ significantly. The result shows that the experimental group subjects have significantly outperformed their peers in control group (t(26)=3.47, p<0.05).

C. Cognitive load

The induced cognitive load using mind-mapping stimulation method and the cognitive load caused by conventional method were compared. The cognitive load was measured using NASA TLX. Table 2 shows a mean for the induced cognitive load from both methods.

All in all, the control group yielded higher cognitive load (M=5.79; SD=2.72) compared to experimental group (M=3.86; SD=1.61). T-test was conducted to determine whether those scores are different significantly. The analysis output indicated that students in experimental group has experienced lower cognitive load significantly compared to control group students (t(26)=2.28; p=0.03).

D. Relationship Between Cognitive Load and Students’ Achievement

In order to see the relationship between the cognitive load and students’ achievement. We correlated the cognitive load and the post test scores by means of Pearson Correlation Test. The test result demonstrate a negative correlation with medium level (r(28)= – 0.50, p<0.01).

IV. DISCUSSION

A. Is there any significant difference between conventional teaching method with mind-mapping method?

The achievement of students are important in the education system as the result of a certain student directly reflects the understanding of the student towards the subject taught by teachers. The better the achievement, the better the teaching delivered by the educator. This is agreeable with Efstatios et.al's research saying that the main reason of students’ poor achievement in Science and Mathematics are due to the mundane teaching method practiced henceforth leaving the students uninterested [10]. Thus, advocating mind-mapping technique is effective in instilling student's interest in understanding mathematics concept. This is on par with the results of this research. Our results show that there is a significant difference between the achievement of the student control group students and the experimental group students.
The students who used mind-mapping technique yielded higher achievement as compared to the students who followed conventional teaching.

**B. What is the level of Cognitive load induced by mind-mapping technique?**

It is widely accepted that cognitive load is considered as one of the factors influencing the achievement of the students [11,12]. This is tallying with Clark et al. (2006) as he mentions that human's cognitive system has limits. If the system exceeds the limit, disturbances is bound to occur and this disturbance is called cognitive load. He also states that selecting a good teaching method can reduce the cognitive load of students [3].

This research findings showed that mind-mapping method has induced significantly lower cognitive load as compared to conventional method. This result proves that mind-mapping method did not cause students to think exceeding the limit of their cognitive system.

Apart from that, the use of mind map might also mitigate split-attention effect. This effect occurs due to the separation of explanatory text from the graphic. Therefore, students need to analyse and process both sources (text and graphics) in order to construct the new knowledge. Processing information from difference sources might consume more cognitive resources and, as a consequence, the working memory might become overloaded [13].

This occurs usually in conventional method in which the teaching material explains theory well but does not give a clear picture for the students to integrate the knowledge. Thus, students have to interpret information from different sources to gain understanding and this will deliberately increase the cognitive load of the students.

Mind map is used to connect and relate graphically the fragmented learning contents. It guides the students to generate new knowledge by processing, analysing and integrating information from a single source. Therefore, not much cognitive resources are used up and those cognitive resources can be optimally utilised for knowledge construction.

Apart from that, the use of mind map may avoid redundancy effect. Redundancy effect is defined as a phenomenon in teaching where similar information is presented to the students during the learning process [14]. Processing redundant information may consume more cognitive resources and might generate higher cognitive load. Mind map is used as a tool to summarise the learning contents and provides an overview of what have been learnt. Therefore, the redundant information can be easily detected and removed from the mind map.

**C. Relationship between cognitive load with achievement**

The overall result shows that there is a moderate and negative relationship between cognitive load and achievement.

As the correlation value is negative, thus the cognitive load is inversely proportionate with the students' achievement. The lower the cognitive load, the better the students' result. This findings is similar to the research conducted by Sarikhani & Zare [15] who discovered that cognitive load was negatively correlated with learning performance in the domain of chemistry.

From a cognitive load perspective, when a student is faced with low cognitive load, it means that there are more cognitive resources available. These cognitive resources can be benefited by engaging the students into meaningful learning event, such as generating self-explanations for the learning contents [16]. This may help student construct new knowledge representation and problem-solving schema as well as promote higher order thinking [17]. Consequently, the student’s achievement can be improved.

Conversely, if a student experiences cognitive overload, there will be no adequate cognitive resources that allow the student to perform meaningful cognitive activities, such as integrating and restructuring the to-be-learnt contents. As a result, learning is hampered and performance cannot be enhanced.

Taken together, an efficient teaching strategy is the one that is able to increase learning performance and at the same time reduce cognitive load. If a student achieve high performance, but s/he also experience high cognitive load, in such case, the teaching strategy used in the learning process cannot be considered as efficient (see [6, 18]).

**V. CONCLUSION**

The teaching method is an important aspect as it boosts the students' understanding to the concept. Students' achievement can be improved by using a right teaching method. Apart from that, an effective teaching method may also help reduce cognitive load that hinders learning.

Conclusively, this research proves that the use of mind-map technique in teaching and learning process may bring about fruitful result in the domain of Engineering Education. In specific, the students’ achievement can be improved and the cognitive load can be reduced by means of mind mapping technique.

**VI. ACKNOWLEDGEMENT**

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