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A MODEL TO PREDICT STUDENTS' PERFORMANCE BASED ON INSTRUCTORS' PATTERN OF METACOGNITIVE SCAFFOLDING THROUGH DATA MINING ANALYSIS

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ABSTRACT

The purpose of this study is to develop a decision tree model that can predict student's performance based on the mechanisms of metacognitive scaffolding prompted by the instructor in Facebook discussion. Prior to the development of the decision tree model, the study identified the pattern of dominant mechanism of metacognitive scaffolding (MS) prompted by the instructor in Facebook discussion. Additionally, students' academic performance was also investigated. 37 postgraduate's students from the Authoring System course was participated in a pre-experimental, one group pre and post-test research design. The data were mined using WEKA software and calculated based on the frequency of metacognitive scaffolding posted by the instructor in online learning setting which is Facebook group discussion and also students' scores in the performance test. The decision tree model predicts that students who achieved grade A in their study were prone to receive a combination of guidance that focused on: i) the process of learning, ii) the rationale for each tasks and activities by the instructor, iii) encouragements in terms of relationship and collaboration among participants and iv) supervision through feedbacks by the instructor such as giving response towards students' comments. The decision tree model also suggests the appropriate mechanisms of instructor's metacognitive scaffolding; such a technique should be able to contribute to students' performance in learning.

Keywords: *Metacognitive scaffolding, Data mining, Facebook, Performance test*

1. INTRODUCTION

In education, scaffolding is known as a support or guidance. Lev Vygotsky is the first person who coined this term through his renowned Social Development Theory. This theory suggests that one's cognitive development is fairly influence by social interaction that they had with others. He believes that in the process of cognitive development, the community plays an important role. He also believes that learning can occur if there is a social interaction with skilful others [1]. In this theory, there are two main principles known as i) More Knowledgeable Others (MKO) and ii) Zone of Proximal Development (ZPD).

According to Vygotsky's Social Development Theory, More Knowledgeable Others (MKO) is refers to anyone who has better understanding and knowledge ability for example teachers, parents or knowledgeable peers. In brief, MKO are the persons whom the learners seek out supervision in order to perform particular task. While the Zone of Proximal Development (ZPD) is referring to the area between what is known and what is not known by a person during learning. The ZPD is the area in which a person seeks guidance from knowledgeable others. As a result, he/she would later be able to develop his/her own understanding.

Flavell (1976) in his study define metacognition as "one's knowledge concerning one's own cognitive processes" (p. 232). He is referring to both knowledge of cognition and one's ability to regulate and control his own cognitive processes [2]. Other researcher [3] believes that metacognition as one's ability to manipulate their cognitive processes. Though, failure in acquire this ability will result to poor performance in learning especially in problem-solving tasks [4-6]. They also believe that one's metacognition can be guided

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through strategy known as metacognitive scaffolding.

To date, studies have focused on the effect of metacognitive scaffolding on students' learning process and their learning performance. However, researches that focus on understanding the pattern of metacognitive scaffolding and its effect on students' learning success are still absent.

To better understand the pattern of metacognitive scaffolding and its effect on students' learning success, this study aims to: investigate the pattern of dominant mechanism of metacognitive scaffolding prompted by the instructor in Facebook discussion. Besides, this study also seek to identify students' academic performance based on the academic-related discussion with instructor in Facebook. Finally, our aim is to develop a decision tree model that can predict student's performance based on the mechanisms of metacognitive scaffolding prompted by the instructor in Facebook discussion.

2. THEORETICAL BACKGROUND

2.1. Metacognitive Scaffolding

Indeed, it is known that metacognition is not simply be taught or transferred [7]. Yet, researchers believe that metacognition can be trained [8]. Luckin & Hammerton [9], in their study have proposed a guidance namely metacognitive scaffolding to trained student's metacognition in learning. The support simply means to guide student's ability to check their level of understanding and thus to become a person who regulate their own thinking.

Hannafin [10] was a pioneer who coined the term "metacognitive scaffolding". Scaffolding means guidance in educational field. Hence, metacognitive scaffolding is a guidance that establish student's understanding in their learning process between what is known, what is not known and what should be known. It is a strategy that provided by the instructor to establish student's understanding about their own thinking [11,12].

Molenaar et al. [13] pointed out that students should be guided to activate their repertoire of metacognitive activities, metacognitive knowledge and skills and domain knowledge. Thus, it is better for the instructor to have a guideline, a structured pattern of scaffolding students and to assist them to perform better in learning. Therefore, in order to discover the pattern of metacognitive scaffolding, this study used the data mining approach; a decision tree algorithm using WEKA software.

Additionally, in this study, the strategy was adapted from the seven mechanisms of metacognitive scaffolding developed by Reingold et al. [14]. The mechanisms include (MS1) Presenting rationale for task and activities, (MS2) Presenting the relationship between reading items, course objectives and tasks, (MS3) Supporting reflective writing, (MS4) Focusing on the process of learning, (MS5) Encourage relationships among participants, (MS6) Discriminating between conclusion/fact/opinion/hypothesis and, (MS7) Supervising text comprehension.

2.2. Metacognitive Scaffolding and Academic Performance

In a recent study by Miao et al. [15], metacognitive scaffolding is believed to be able to provide support to student in a computer-mediated learning environment. It helps student to reflect upon their learning and re-plan their learning process by continually monitoring and analyzing their actions. This finding seems consistent with other studies that highlighted the importance of having a learning environment that engaged students with metacognitive task, for example, by leading the students to visibly organize and plan their activities and justify their choices of actions. On another note, the metacognitive scaffolding provided by the instructor gives the opportunity to the students to reflect on their learning by monitoring the quality of their thinking [16-17].

Additionally, metacognitive scaffolding provides a systematic approach in assisting student's abilities to inculcate problem solving skills [18-19]. Meanwhile, the metacognitive prompts by the instructors acquire students to perform well in class. Thus, it stimulates their experiential learning [20]. Besides that metacognitive support focuses students' awareness of their own thinking and on understanding the activities they are engaged during learning.

As being mentioned by Gunter et al. [21], metacognitive prompts by instructors could promote student's ability to monitor their own cognitive processes. The instructor can guide students to define their thinking processes by

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recognizing their weakness in understanding the content of learning, and by finding proper ways to overcome the difficulties. This could be one of the factors for the ability of metacognitive support to enhance more effective learning [22]. Other researchers also agreed that by offering metacognitive support in an online learning environment, students can increase their efficiency in learning [23-24]. However, their studies did not formulate any framework or guidelines that can be used by instructors to help students in learning.

2.3. Data Mining

Data mining is known as a method of mining information from raw and large datasets [25]. It is also known as a tool to uncover hidden information from a large volume of data [25]. The process is done through the use of techniques and algorithms drawn from the data mining software. The algorithms used include clustering, association rule mining and decision tree analysis. Data mining has been widely used across different fields including medicine, business, and marketing & sales. Recently, data mining analysis is also applied on educational data.

The mining of educational data has yielded better outcome in terms of students' performance, course development, students' retention and may contribute to the development of institutional standard [26]. Usually, the applications are used to predict students' behavior, performance and examination. Such prediction will help the instructors to pinpoint student's weaknesses in learning and assist them to achieve better performance. It also serves as a guideline for the instructors to provide students with sufficient support for a meaningful learning.

Other than that, additional useful information mined from the data can help the instructors to detect useful patterns of students' preferences in learning especially in the online learning environment. Valuable data from the database such as student's academic background, financial status and online learning participation level (log data from online learning management system) are examples of the useful data that can be used to understand their preferences in learning. Thus, this will help institutions to predict future behaviors of students from a certain area of concern [26-27]. For instance, Kovacic [28] conducted a case study on educational data mining that utilized student's enrollment data to predict student's performance in learning.

Data mining has attracted a considerable amount of attention in turning digital data into useful information and knowledge [27]. A number of data mining techniques such as decision tree analysis, association rule mining and clustering analysis have been conducted to perform different knowledge tasks [27] Due to its proficiency and high accuracy, the decision tree algorithm is ideal for classifying datasets [29]. In this study, we have conducted a decision tree analysis to predict student's performance based on the pattern of metacognitive scaffolding provided by the instructor in an online learning environment.

3. METHODOLOGY

This study used a quantitative research design with pre-experimental one group pre and post-test approach. A total of 37 postgraduate students from the Authoring System course involved, out of which 27 (73%) were female and 10 (27%) were male. More than half of the participants (22 participants) aged between 25 and 30 years old, while 13 participants aged less than 40 years old and 2 participants aged 41 years old or more. 27 of the participants hold a Degree in Education, 8 of the participants hold a Degree in Computer Science and 2 of the participants hold a Degree in Social Science (Psychology & Counselling).

The instruments selected for the research were online discussion transcripts and students' scores in a performance test. Instructor's scaffolding were coded based on the mechanisms of metacognitive scaffolding by Reingold et al. [14]. Table 1 denotes the mechanisms of metacognitive scaffolding along with instructor's posting in Facebook.

Table 1: Instructor's Metacognitive scaffolding in online discussion

Metacognitive Scaffolding (MS)	Example of instructor's posting
MS 1: Presenting rationale for task and activities	"Ali developed a text entry question in flash and he was using static text as a place where users will type the answer of the question. When he executed the file, the user can see the blinking cursor in a place where they can type the answer."

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MS 2: Presenting the relationship between reading items, course, objectives and tasks	"How can you relate between the concept of what we have learned before (in Topic 1, 2 and 3) and creating different kinds of applications in flash (in Topic 4)?"
MS 3: Supporting reflective writing	"Thank you for your opinion, keep up the good work."
MS 4: Focusing on the process of learning	"If you increase the number of fps, what will happen to your animation and your file size in byte?"
MS 5: Encourage relationship among participants	"What are your comments on your friend's answer?"
MS 6: Discriminating between conclusion / fact / opinion / hypothesis	"Describe the differences between motion tweening and shape tweening? Your explanation should come with an appropriate example."
MS 7: Supervising text comprehension	"Can you share with us what animation technique you use along with the process?"

While students' scores were taken from the performance test which includes 12 structured questions related to the topic of learning Adobe Flash software. The rubric used for students' scores are reported in Table 2.

Table 2: Grading scheme

Grade	Score
A	80-100
B	70-79
C	60-69
D	50-59
E	0- 49

Content expert was employed to test the validity of the performance test. In terms of reliability, a test-retest reliability was employed in which the same test was conducted by running it at different points of time. This will lead to determine the reliability of the test. The test was given to a group of subjects in two separate occasions. The correlation coefficient value for test-retest reliability in this study is 0.738 which is considered good.

3.1 Procedure and Analysis

The study was conducted for seven weeks. Throughout the seven weeks of study, the instructor outlined a discussion plan in the Facebook group page. To facilitate students in their learning process, the instructor have triggered the discussion through the use of metacognitive scaffolding mechanism. Meanwhile, the students' comments and responses in the Facebook group page were also monitored and analysed in order to encourage them to actively participate in the discussions.

Consequently, the researcher also predicted the type or mechanism of metacognitive scaffolding that would influence the students' performance through a decision tree analysis. In this stage, Instructor's post is coded and calculated based on the mechanisms of metacognitive scaffolding. The data is represented each student's data based on the total number of metacognitive scaffolding received from instructor along with their post-test score. Figure 1 illustrates a raw data that further will be uploaded in WEKA software.

```
@relation msandperformance

@attribute ms1 numeric
@attribute ms2 numeric
@attribute ms3 numeric
@attribute ms4 numeric
@attribute ms5 numeric
@attribute ms6 numeric
@attribute ms7 numeric
@attribute score {a,b,c}

@data                   8,0,11,13,8,2,2,b       2,1,6,10,6,1,3,b
9,1,15,19,7,0,2,a       2,1,8,12,3,2,1,a        13,0,3,12,3,0,2,a
17,1,15,16,7,0,3,a      2,0,4,11,2,0,1,c        2,0,3,5,2,0,0,c
35,0,24,27,25,1,6,a     6,0,7,5,1,3,0,b         0,0,5,8,2,3,0,b
15,0,6,2,1,0,1,a        7,0,4,2,1,0,2,c         0,0,6,12,9,1,1,c
5,1,2,16,2,0,0,a        6,0,10,12,5,3,2,a       1,0,5,14,3,0,2,b
7,2,11,9,4,1,4,a        6,0,9,17,5,0,2,a        14,0,12,12,5,0,11,a
7,0,8,9,6,0,1,b         6,0,8,14,9,3,3,b        14,2,6,23,8,3,11,a
```

Figure 1: Some parts of raw data of metacognitive scaffolding and post test score received by each student

4. Results

4.1. Pattern of Dominant Mechanism of Metacognitive Scaffolding

Instructor's pattern of metacognitive scaffolding posting in Facebook discussion was examined through extracted data. The data is taken from the discussion transcript in a Facebook group discussion page using content analysis technique. The messages from the instructor are coded and calculated in terms of frequency. Table 3 indicates total numbers of instructor's post based on different mechanisms of metacognitive scaffolding.

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Table 3: Total number of post of instructor's metacognitive scaffolding

Mechanisms of metacognitive scaffolding	Total number of post
MS 1: Presenting rationale for task and activities	268*
MS 2: Presenting the relationship between reading items, course, objectives and tasks	16
MS 3: Supporting reflective writing	302*
MS 4: Focusing on the process of learning	426*
MS 5: Encourage relationships among participants	200*
MS 6: Discriminating between conclusion/ fact/ opinion/ hypothesis	33
MS 7: Supervising text comprehension	104*

Note: * indicates the dominant mechanisms of instructor's metacognitive scaffolding

Studies revealed that instructor frequently prompting four mechanisms of metacognitive scaffolding (MS) especially in the form of supporting the students to focus and emphasize their learning process. MS4 ranked the highest with 426 messages posted by the instructor throughout the study. In addition, supporting student's reflective writing ranked the second with a total of 302 messages, and it is being followed closely by the kind of support that assist the students to present their rationale for the tasks and activities involved. Finally, the instructor also seems frequently encourage the students to assist their peers by promoting the relationship among the participants and supervising text comprehension, by asking further about their progress in learning.

4.2. Students' Academic Performance

Besides understanding instructor's pattern of metacognitive scaffolding, the researcher also attempted to understand how the metacognitive scaffolding could assist students. In this case, the researcher had collected the minimum and maximum scores, the mean, and also the standard deviation gained by the students in pre and post-tests assessment. Table 4 shows the analysis of student's score in pre and post-test.

Table 4: Descriptive analysis of student's maximum and minimum scores, means and standard deviation in pre-test and post-test assessment

	n	min	max	mean percentage	sd
pre-test	37	3	46	26.89	9.944
post-test	37	63	100	83.46	11.594

37 students participated in this pre and post-test assessment. The total percentage for both assessments is 100 percent. The average pre-test score is 26.89% (minimum score is 3 and maximum score is 46). Meanwhile, the average post-test score is 83.46%, minimum score is 46% and maximum score is 100%). The result indicates a mean difference between pre and post-test score. It shows that students' performances have improved after being scaffolded by the instructor.

Figure 2 illuminates the differences between the results of students' pre and post-test scores in this study. The graph shows a huge difference between student's pre-test scores and post-test scores. Additionally, there are about five students who scored full marks in post-test.

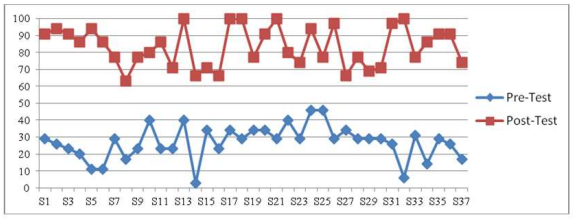

Figure 2: Comparisons of students' pre-test and post-test scores

4.3. Decision Tree Model

A decision tree which consists of two nodes which are the root node and leaf node was generated [30]. The root node represents the metacognitive scaffolding and the leaf node represents the scores. Figure 3 illustrates the decision tree model.

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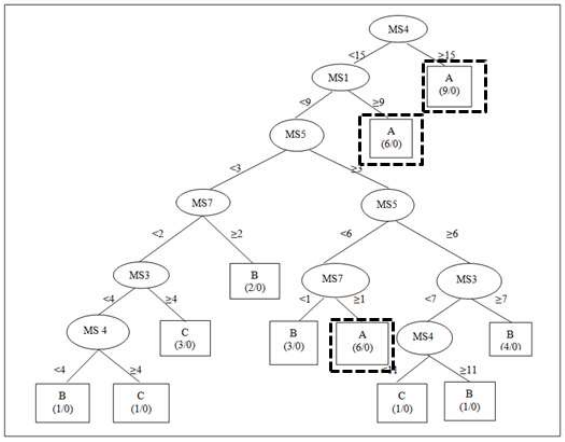

Figure 3: Decision tree model generated by WEKA software

Figure 3 shows the decision tree model generated by data mining software named WEKA software version 3.6.6. The decision tree model was generated using a full dataset with training set mode. It was constructed using Random Tree classifier. The classifier uses the attributes of the instructors' metacognitive scaffolding (MS) to make decision.

A total of 21 nodes derived from this model. A square box or known as leaf nodes illustrate the student's score in the post-test assessment. The number in the brackets indicates the class label. This class label contains both; the number of students who scores specific grade and the number of students that is incorrectly classified as a result. From the output, it shows that none of the students are incorrectly classified.

The dataset was split into several attributes with MS4 (mechanisms that allow students to focus on the process of learning) at the top of the tree structure. This has revealed that MS4 being the highest number of MS posted by the online instructor throughout the discussion in Facebook. . The tree specifically shows that, nine students who received grade A in their study would receive 15 or more posts related with MS4. Another 6 students who obtain grade A received a certain amount of and a combination of MS1 (mechanism that helps students to focus on their learning) and MS4. Finally, another 6 students who obtained Grade A received a combination of MS1, MS4, MS5 (mechanism that encourage the relationship among participants) and MS7 (mechanism that supervise students text comprehension; in this way, the instructors must refers to previous statements posted by the students before commenting or asking the students regarding their progress in learning).

The decision tree model shows that there are 21 students who obtain grade A, 11 students obtain grade B and there are 5 students who obtain grade C in this study. From the decision tree model, one can actually predict the path in terms of which metacognitive scaffolding is best to be used in order to make sure students received grade A in their learning. Additionally, the decision tree model shows the exact quantity of metacognitive scaffolding posts to be prompted by online instructor to assist students received better grades in their learning.

5. Discussions

Instructor often assists the students to focus on the process of learning, yielding a total number of 426 messages posted by the instructor throughout the study (see Table 3). The outcome shows that this mechanism has a great potential to assist students throughout their learning process. Indirectly, this support has able to increase student's knowledge and competence. As all of us are aware of the importance of scaffolding in educational process, supplying this kind of support is critical so that student's engagement, immersion and motivation could also be compromised [31]. Results also revealed that instructor often guide the students to provide rationale for each task and activity. In this sense, the instructor often instructs students to explain the rationale behind each task and provide justification for their answers. By having this, students are aware of their cognitive level by being able to elaborate on each action they took to complete tasks in hand. These results reflect those of Staples [32] who did a study about student justification in Mathematics classroom, she found that students who are able to expressing their justifications for all tasks are those who have higher marks than those who are not.

Findings also shown that instructor often supports student's reflective writing. This mechanism indicates a situation where the instructor evaluates, comments or give feedbacks on student's answers. This finding suggests that the goal of supporting reflective feedback is to encourage students to write more, to share opinions with others and to make sure they monitor their own learning [33]. Good remarks from the instructor can boost student's desire to continue sharing.

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Due to the fact that students also benefit something through the support of their peers, the instructor is likely to encourage students to assist their peers by promoting the relationship among the participants in Facebook discussion. This finding corroborates the ideas of Furrer et al. [34] who suggested that relationship among peers as a central space for the development of students' academic engagement and achievement. In this study, the instructor often promotes the relationship among students by using the tagging function in Facebook page. Whenever the instructor requires the engagement among students, the instructor will tagged their names to help their friends to answer certain problems.

Besides through the use of metacognitive scaffolding as a guidance to support students learning, the finding also shows metacognitive scaffolding was found to have significant effect on the students' performances based on the higher mean value of the students' post-test scores (see Table 4). In fact, all of the students performed well in their post-tests compared to their pre-tests (see Fig 2). Such a discovery is in agreement with Luckin and Hammerton's [9] finding, which showed that students can be scaffolded to a greater achievement via metacognitive scaffolding. The results obtained also corroborated those of other studies' [35,14] which showed that metacognitive scaffolding is able to generate students cognitive thinking process whereas students in this study shown that they are capable to reflect on their tasks (giving feedback). This might be due to the mechanisms of metacognitive scaffolding used in the current study. The interaction and instruction by using the mechanisms of metacognitive scaffolding is initially planned earlier before it were given to the students, it aims is to trigger the students' learning process in Facebook [36]. We believed that Facebook is capable to attract student's interest in learning and able to be a platform for meaningful learning [36]. Among the procedure involved are, the online instructor initiate the discussion by prompting questions following the guideline by the mechanism of metacognitive scaffolding. The prompted messages were purposively prompted to initiate the discussion sessions in the Facebook group page between the instructor and the students. As the discussion goes on, the instructor reply based on the feedback from the students. Jumaat et. al. [37] also agreed that in order to promote interactive learning experience in an online learning environment, researchers must implement a strategic planning of interaction beforehand.

Besides, in this study, the researcher had used Facebook as a social networking tool platform for the discussion between instructor and students. This has also plays a major role in supporting students learning process in online discussion. Findings from this study revealed that Facebook has the potential to promote informal dialogue and knowledge sharing among students. This has clearly shown that students in this study has the ability to use Facebook for academic related discussion. Furthermore, online instructors also supporting student's learning process through series of guidelines by using the mechanisms of metacognitive scaffolding.

Jumaat and Tasir [38] also agreed that online instructor plays a major role in making sure students are engaged and involved well in the discussion especially academic related content. Not just that, online instructor also motivate the students to take part actively in the discussion session.

Besides that, the study was also confronted with the determination to produce a predictive model of metacognitive scaffolding that leads to students' performances in learning. Students' performances were predicted by the kind of mechanism of metacognitive scaffolding (MS) and the amount of MS received by the students.

The model predicts that students who achieved grade A in their study were prone in receiving the combination of guidance that aimed for them to focus on the process of learning (MS4), the assistance in which instructor presenting rationale for task and activities (MS1), a guide from instructor who encourage the relationship among participant (MS5) and when instructors supervising text comprehension (MS7) like giving response and feedbacks towards students' comments. This proved that the combination of these mechanisms does have any impact on the students' performance in learning. It is interesting to note that those mechanisms were the dominant mechanisms of metacognitive scaffolding used by the instructor as reported earlier in the study. Thus, it was not surprising that most of the students (21 out of 37 students) have obtained grade A in the present research. The prediction model was beneficial as it had informed the instructor about which mechanism of metacognitive scaffolding that can be used to assist the students in achieving certain grades.

However, in this study, the model is only relies on the dominant mechanisms of

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metacognitive scaffolding without looking into other instructional scaffolding mechanisms such as procedural, conceptual and strategic scaffolding which could possibly bear different outcome towards student's performance.

6. Conclusion

This study provides a practical implication especially for online instructors, students and also policy makers. From this study, we can conclude that instructors play a vital role in monitoring and guiding the students throughout the discussion session in online learning environment. This study also demonstrated that online instructors stimulate several mechanisms of metacognitive scaffolding as their core teaching strategies while assisting the students throughout their process of learning.

Data mining is a powerful tool that enables researchers especially educators and educational institutions to better allocate resources and efficiently manage student outcomes in learning. It is able to uncover hidden information from large datasets[39], and allow educational institutions to achieve better educational standard. As such, the goal of education to serve the nation and inspire the society to acquire knowledge and skills that will benefit them in the future can be reached. This study is intended to enhance the quality of learning. The prediction model is beneficial as it informs the instructor regarding which mechanism of metacognitive scaffolding can be used to assist students in achieving certain grades.

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