METACOGNITIVE SKILFULNESS OF STUDENTS IN PROBLEM SOLVING

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METACOGNITIVE SKILFULNESS OF STUDENTS IN PROBLEM SOLVING

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Abstract

The relationship between metacognition in learning and problem solving has been extensively studied. The importance of metacognition in learning and problem solving has also been studied methodically. We conducted this study to assess the metacognitive skilfulness of students during problem solving. The aim of the study was to gain a better understanding on how students assess their problem solving skills and activities. The participants were asked to solve a Tower of Hanoi on paper, consisting of 3 discs before completing the Metacognitive Activities Inventory questionnaire. All the 29 students solved the puzzle in the allocated time. The participants have demonstrated that they exercise metacognitive skills during problem solving. Metacognitive skilfulness is significant (p<0.05). Both males and females practice metacognitive skills during problem solving, although females practiced metacognitive skilfulness slightly more than males. 5 students have demonstrated more metacognitive skilfulness by solving the puzzle mentally. The findings confirm that metacognition is an integral part of cognitive processes.

Key Terms: Metacognition, Problem Solving, Metacognitive Skills

1. Introduction

Metacognition is defined as the active regulation and orchestration of cognitive processes (Flavell, 1976). Other authors have defined metacognition as the awareness of one's thoughts (Kuhn & Dean, 2004) or the control and monitoring of thought (Martinez, 2006).
According to Anderson (1985), problem solving is defined as any goal-directed sequence of cognitive operations. Metacognition is an important factor in the prediction of learning performance (Jacobse & Harskamp, 2012). Metacognition is an important predictor in traditional learning environments (Dignath & Büttner, 2008; van der Stel & Veenman, 2010; Wang, Haertel, & Walberg, 1990) and computerised learning environments (Veenman, 2008). Various studies have shown that there is an intricate relationship between metacognition and problem solving (Anandaraj & Ramesh, 2014; Mokos & Kafoussi, 2013). On the other hand, Brown (1978) stipulated that metacognitive skills "are the regulatory activities associated with solving problems". In problem solving literature, the Tower of Hanoi is a very popular problem to provide simulation and explanations of human problem solving. The Tower of Hanoi is a well-used task in cognitive science and has contributed much to many theories of problem solving (Anderson, Kushmerick, & Lebiere, 1993; Anzai & Simon, 1979; VanLehn, 1991). A process-based approach for the development of problem solving can trigger students' awareness of their own thinking processes by prompting with procedural questions such as; what are you doing? Why are you doing it? and How does it help you? (Schoenfeld, 2014). However, previous studies employing self-reporting questionnaires were not representative of students' metacognitive behaviour. Hence, there is a need to assess the metacognitive skillfulness accurately. The objective was to measure the metacognitive skillfulness of students in problem solving.

2. Literature Review

Metacognition being the thoughts of one’s thoughts, including the awareness of one’s thoughts, that is, metacognitive knowledge, what one can do, that is, metacognitive skills and what one knows about one’s cognitive abilities, that is, metacognitive experience (Biryukov, 2004). The benefits of metacognitive skills for problem solving have been elaborated in previous studies. Metacognitive skills are the regulation and control of one’s cognitive processes and learning activities (Brown, 1978; Flavell, 1992; Schraw & Moshman, 1995). Furthermore, Veenman (2012) purported that one’s learning behaviour is regulated and controlled by metacognitive skills and that these skills are demonstrated by; orientation, goal setting, planning, monitoring, checking, evaluation and recapitulation. As a matter of fact, van der Stel & Veenman (2008) concluded that metacognitive skillfulness accounted for 40% of variance in learning outcomes.

Moreover, Schraw & Moshman (1995) has elaborated on the distinction between metacognitive knowledge and metacognitive regulation. The authors support that knowledge of cognition refers to what individuals know about their cognition. Knowledge of cognition includes three different kinds of metacognitive awareness; declarative, procedural and conditional knowledge. On the other hand, regulation of cognition concerns metacognitive activities that help in controlling one’s thinking and learning. Such regulatory skills are planning, monitoring and evaluation.

Metacognitive skills can be considered as a set of metacognitive instructions for the monitoring and control of cognitive processes (Veenman, 2012). Learning behaviour and learning outcomes are directly affected by these skills (Veenman, 2008). Metacognitive skillfulness is an aptitude in how learners interact with their learning environments (Snow, 1989). Under that optic, Veenman, Van Hout-Wolters, & Afflerbach (2006) suggest that an in-built feedback mechanism is incorporated in metacognitive skills, meaning that one can either plan his/her actions during a task or one cannot and therefore go astray.

Self-reporting questionnaires are the best methods to measure metacognition. Some examples are; the Motivated Strategies for Learning Questionnaire (Pintrich & De Groot, 1990) and the Metacognitive Awareness Inventory (Schraw & Dennison, 1994). These instruments contain about the metacognitive monitoring and regulation of respondents depending on how these statements apply to them. The advantage of using such questionnaire is that can be administered to large populations easily (Schellings & Van Hout-Wolters, 2011). The Metacognitive Activities Inventory (MCAI) (Cooper & Sandi-Urena, 2009), consists of 27 self-
reporting statements to assess the metacognitive skilfulness of students. Respondents respond to the statements on a 5 point Likert scale (1, Strongly Disagree to 5, Strongly Agree).

3. Research Design and Methodology

In this study, 29 students enrolled in the 3rd year Bachelor of Computer Science from a public university in Malaysia participated. The participants were recorded as 12 males and 17 females. The purpose of this study was to measure the metacognitive skilfulness of students in problem solving. The participants were asked to solve a Tower of Hanoi consisting of 3 discs before completing the MCAI questionnaire. The participated were asked to indicate their moves while they solve the problem. A separate sheet containing empty poles were provided to them to work out their moves. After solving the Tower of Hanoi puzzle, the participants were asked to answer the MCAI questionnaire. The MCAI questionnaire consists of 27 statements, with a Likert scale ranging from 1-Strongly Disagree to 5-Strongly Agree. Eight statements are negatively coded to avoid that the respondents agree to all the statements without giving thought (Cooper and Sandi-Urena, 2009). The participants were allocated 20 minutes to solve the puzzle and 30 minutes to complete the questionnaire.

4. Results and Discussion

All the 29 students (100%) solved the puzzle in the allocated time. 5 students did not use the separate sheet of empty towers to work out their moves and solved the puzzle mentally. According to Table 1 below, we can see that the participants have demonstrated that they exercise metacognitive skills during problem solving. Metacognitive skilfulness is significant (p<0.05) for both males and females. However, at the same time, we noted that females have shown to demonstrate more metacognitive skilfulness in the problem solving process.

Table 1: Gender Metacognitive Skillfulness

| Statement/Gender | Kolmogorov-Smirnov Statistic | df | Sig. | Shapiro-Wilk Statistic | df | Sig. |
|------------------|-----------------------------|----|------|------------------------|----|------|
| 1 Male           | .257                        | 12 | .028 | .807                   | 12 | .011 |
| Female           | .380                        | 17 | .000 | .632                   | 17 | .000 |
| 2 Male           | .354                        | 12 | .000 | .732                   | 12 | .002 |
| Female           | .324                        | 17 | .000 | .774                   | 17 | .001 |
| 3 Male           | .279                        | 12 | .011 | .784                   | 12 | .006 |
| Female           | .257                        | 17 | .004 | .799                   | 17 | .002 |
| 4 Male           | .364                        | 12 | .000 | .753                   | 12 | .003 |
| Female           | .437                        | 17 | .000 | .594                   | 17 | .000 |
| 5 Male           | .303                        | 12 | .003 | .734                   | 12 | .002 |
| Female           | .224                        | 17 | .024 | .812                   | 17 | .003 |
| 6 Male           | .250                        | 12 | .037 | .828                   | 12 | .020 |
| Female           | .300                        | 17 | .000 | .798                   | 17 | .002 |
| 7 Male           | .323                        | 12 | .001 | .780                   | 12 | .006 |
| Female           | .265                        | 17 | .003 | .815                   | 17 | .003 |
| 8 Male           | .309                        | 12 | .002 | .768                   | 12 | .004 |
| Female           | .382                        | 17 | .000 | .680                   | 17 | .000 |
| 9 Male           | .213                        | 12 | .139 | .811                   | 12 | .012 |
| Female           | .355                        | 17 | .000 | .787                   | 17 | .001 |
| 10 Male          | .309                        | 12 | .002 | .768                   | 12 | .004 |
| Female           | .243                        | 17 | .009 | .809                   | 17 | .003 |
|   | Male          | Female       |   | Male          | Female       |
|---|---------------|--------------|---|---------------|--------------|
| 11| .238          | .257         | 12| .059          | .004         |
|   |               |              |   | .840          | .797         |
|   |               |              |   | 12            | 17           |
| 12| .309          | .315         | 12| .002          | .000         |
|   |               |              |   | .768          | .785         |
|   |               |              |   | 12            | 17           |
| 13| .300          | .237         | 12| .004          | .012         |
|   |               |              |   | .809          | .819         |
|   |               |              |   | 12            | 17           |
| 14| .257          | .394         | 12| .028          | .000         |
|   |               |              |   | .807          | .678         |
|   |               |              |   | 12            | 17           |
| 15| .309          | .237         | 12| .002          | .012         |
|   |               |              |   | .768          | .819         |
|   |               |              |   | 12            | 17           |
| 16| .417          | .243         | 12| .000          | .009         |
|   |               |              |   | .608          | .809         |
|   |               |              |   | 12            | 17           |
| 17| .398          | .295         | 12| .000          | .000         |
|   |               |              |   | .699          | .859         |
|   |               |              |   | 12            | 17           |
| 18| .209          | .224         | 12| .153          | .024         |
|   |               |              |   | .824          | .812         |
|   |               |              |   | 12            | 17           |
| 19| .300          | .225         | 12| .004          | .022         |
|   |               |              |   | .809          | .806         |
|   |               |              |   | 12            | 17           |
| 20| .245          | .243         | 12| .044          | .009         |
|   |               |              |   | .895          | .809         |
|   |               |              |   | 12            | 17           |
| 21| .299          | .285         | 12| .004          | .001         |
|   |               |              |   | .863          | .792         |
|   |               |              |   | 12            | 17           |
| 22| .382          | .306         | 12| .000          | .000         |
|   |               |              |   | .790          | .856         |
|   |               |              |   | 12            | 17           |
| 23| .193          | .275         | 12| .200*         | .001         |
|   |               |              |   | .897          | .862         |
|   |               |              |   | 12            | 17           |
| 24| .205          | .213         | 12| .174          | .040         |
|   |               |              |   | .891          | .885         |
|   |               |              |   | 12            | 17           |
| 25| .250          | .220         | 12| .037          | .028         |
|   |               |              |   | .921          | .859         |
|   |               |              |   | 12            | 17           |
| 26| .200          | .258         | 12| .198          | .004         |
|   |               |              |   | .914          | .871         |
|   |               |              |   | 12            | 17           |
| 27| .214          | .295         | 12| .136          | .000         |
|   |               |              |   | .891          | .859         |
|   |               |              |   | 12            | 17           |

4.1 Normality Test

The skewness falls between 0.504 and -0.504, indicating that the data is symmetric. The kurtosis lies between 1.56 and -1.303, showing that the data is in an acceptable range. The descriptive statistics are shown in Table 2.

### Table 2: Test of Normality

| Statement | N  | Skewness | Kurtosis |
|-----------|----|----------|----------|
| Normality |    |          |          |
The Metacognitive Activities Inventory consists of 27 statements, with a Likert scale ranging from 1-Strongly Disagree to 5-Strongly Agree. Eight statements are negatively coded to avoid that the respondents agree to all the statements without giving thought (Cooper and Sandi-Urena, 2009). The total score for the questionnaire is 135 for the 27 statements. Observation of the data revealed that the participants scored less from statements 20-27, which were negatively coded. This indicates that the participants were not confused about the statements and understood them well. Table 3 shows the total score of the participants.

Table 3: MCAI Scores of Participants

| Statement | N | Sum | Valid | Missing |
|-----------|---|-----|-------|---------|
| 1-27      | 29|     |       |         |

Valid N (listwise) 29
|   |   |   |   |   |
|---|---|---|---|---|
| 1 | 29 | 0 | 126.00 |
| 2 | 29 | 0 | 122.00 |
| 3 | 29 | 0 | 124.00 |
| 4 | 29 | 0 | 119.00 |
| 5 | 29 | 0 | 117.00 |
| 6 | 29 | 0 | 115.00 |
| 7 | 29 | 0 | 119.00 |
| 8 | 29 | 0 | 121.00 |
| 9 | 29 | 0 | 115.00 |
| 10 | 29 | 0 | 124.00 |
| 11 | 29 | 0 | 114.00 |
| 12 | 29 | 0 | 118.00 |
| 13 | 29 | 0 | 118.00 |
| 14 | 29 | 0 | 112.00 |
| 15 | 29 | 0 | 122.00 |
| 16 | 29 | 0 | 117.00 |
| 17 | 29 | 0 | 112.00 |
| 18 | 29 | 0 | 115.00 |
| 19 | 29 | 0 | 116.00 |
| 20 | 29 | 0 | 108.00 |
| 21 | 29 | 0 | 108.00 |
| 22 | 29 | 0 | 100.00 |
| 23 | 29 | 0 | 76.00 |
| 24 | 29 | 0 | 106.00 |
| 25 | 29 | 0 | 77.00 |
| 26 | 29 | 0 | 92.00 |
| 27 | 29 | 0 | 90.00 |

### 4.2 Predictors
In order to determine which statements were most important and least important from the participants’ responses, a linear regression analysis was conducted. Statement 14 was noted as the most important predictor and statement 22 was noted as the least important predictor from the questionnaire. As pointed out by (Brown, 1978), the majority of the participants responded positively to the statement, indicating that they employed skills such as “predicting, checking, monitoring, reality testing and coordination and control to solve problems”. On the other hand, metacognitively skilled students are more likely to focus on relevant information in a given task and draw an appropriate action plan as supported by (Veenman, Elshout, & Meijer, 1997). Table 4 and Table 5 show that most important and the least important predictors.

### Table 4: Most Important Predictor

| Statement                                                                 | Gender | N   | Mean | Std. Deviation | t    | df  | Sig. (2-tailed) |
|---------------------------------------------------------------------------|--------|-----|------|----------------|------|-----|-----------------|
| 14. I find important relations among the quantities, factors, or concepts involved before trying a solution. | Male   | 12  | 4.25 | 0.75378        | 2.593| 27  | 0.015           |
|                                                                           | Female | 17  | 3.5882 | 0.61835      | 2.504| 20.718 | 0.021           |

### Table 5: Least Important Predictor

| Statement                                                                 | Gender | N   | Mean   | Std. Deviation | t    | df  | Sig. (2-tailed) |
|---------------------------------------------------------------------------|--------|-----|--------|----------------|------|-----|-----------------|
| 22. Once I know how to solve a type of problem, I put no more time in understanding the concepts involved. | Male   | 12  | 3.5833 | 1.24011        | 0.592| 27  | 0.559           |
|                                                                           | Female | 17  | 3.3529 | 0.86177        | 0.556| 18.314 | 0.585           |

5. **Conclusion**

The aim of this study was to gain a better understanding of how students assess their problem solving skills and activities. Previous studies to assess the metacognitive skilfulness of students have reported contradicting results on how students develop metacognitive skills. The issue of whether metacognitive skills are general or domain-specific have been addressed but was not conclusive. This study has shown that students have continuously exercised metacognitive skills during problem solving. The participants were presented with a Tower of Hanoi consisting of three poles to solve. After solving the problem, the participants completed the MCAI questionnaire. From the findings, it was found that the participants do practice metacognitive skills while they were engaged in the task of solving the Tower of Hanoi puzzle. This shows that metacognition, specifically, metacognitive skills is an integral part of cognitive
processes. Further investigation is required to establish which strategies do students use in problem solving and the related metacognitive strategies.

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