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# THE IMPORTANCE OF MONITORING SKILLS IN PHYSICS PROBLEM SOLVING

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**Abstract:**
The purpose of this paper is to show how important "monitoring" is as metacognitive skills in solving physics problems in the field mechanics. Based on test scores, twenty one students were divided into two groups: more successful (MS) and less successful (LS) problem solvers. Students were allowed to think-aloud while they worked on their problems. Each of the students was videotaped, and interviewed right after the task. A schema was used to grade the written answers. As a conclusion "monitoring" appeared as a very important metacognitive skill leading to successfully solving problems in mechanics.

**Keywords:** more successful vs less successful, problem solving, force and motion, metacognition, thinking aloud

## Introduction

Metacognition was described by Davidson et al., (1994) as an important process that contributes to problem solving performance. Metacognition helps problem solvers to identify and define the problems; mentally represent the problems; plan how to proceed; evaluate what one knows about one's performance (Davidson et al., 1994). Sternberg (1998) listed 12 characteristics that expert problem solvers use and monitoring is one of them.

Several studies have shown that metacognition is either lacking or absent in situations where students do not solve the problem successfully - that there is an

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absence of consistent monitoring and regulating of the problem solving processes (Artzt & Armour-Thomas, 1992); without metacognitive monitoring, students are less likely to take one of the many paths available to them and are less likely to arrive at an elegant mathematical solution (Yimer & Ellerton, 2006); the absence or lack of metacognition causes students to fail to solve the problem successfully (Biryukov, 2004; Foong, 1990; Kramarski, Mevarech, & Arami, 2002).

Research in metacognition has shown it to be a factor that can enhance problem solving performance (Kramarski et al., 2002; Özsoy & Ataman, 2009; Phang, 2009). Heller (2002) claims it helps students monitor understanding, ask skeptical questions, and reflect on their own learning processes. In addition, Davidson, Deuser, and Sternberg (1994) also argue in favour of metacognition because it helps the problem solver to see that there is a problem to be solved, work out exactly what the problem is, and understand how to reach the solution. Moreover, Fernandez, Hadaway, and Wilson (1994), claim that metacognitive skills are important strategies to manage problem solving.

Phang (2009) identified five metacognitive skills. The students were 14-19 years of age, studying Physics and living in the UK. He identified them as monitoring, reflecting, regulating, evaluating and justifying. He identified that example monitoring is thinking of the concepts that might be related, and this helps students understand or solve the problem.

Chi et al., (1989) analysed self-explanation of good and poor problem solvers in physics as they studied examples and solved problems. This study shows that good problem solvers produced more self-explanations compared to poor problem solvers because they actively and accurately monitored their comprehension of the examples. For Chi self-explanation refers to as ideas which say only something substantive about physics. Even though poor students were observed to produce more monitoring statements than good students, good students produced greater number of explanation with a foundation in physics than the poor student counterparts. Ferguson-Hessler and de Jong (1990) supported Chi et al., (1989) findings. According to them, good problem solvers produce more self-explanations and become better at detecting comprehension failures by monitoring their comprehension.

## Methodology

This study employed a qualitative research design and the "think aloud method" was chosen to collect and analyse the data. This method was the most appropriate because it voids interpretation by the subject and only assumes a very simple verbalization process. Secondly, the think aloud method treats as data the verbal protocols, that are accessible to anyone, thus creating an objective method (Van Someren, Barnard, & Sanberg, 1994).

This study consisted of 21 students, with a physics background at the university level. Ten students were involved in the first fieldwork and eleven in the second fieldwork. The purpose of the first fieldwork was to check the difficulty of the physics task (Physics Problem Solving Achievement Test) and to refine the coding schemes called Coding Metacognitive in the Thinking Aloud Protocol (CMBTAP).

All of the respondents solved four physics problems in a pencil and paper test. The following is an example of the "lift" problem that has been adapted from the University of Minnesota (2011).

You have always been impressed by the speed of the lift at C22 at the Faculty of Science especially compared to the one in the C20 Physics Department. You wonder about the maximum acceleration for this lift during normal operation, so you decide to measure it by using your bathroom scale. While the lift is at rest on the ground floor, you get in, put down your scale, and stand on it. The scale reads 59 kg. You continue standing on the scale when the lift goes up, carefully watching the reading. During the trip to the 4th floor, the greatest scale reading was 82 kg.

The name of the assignment was Physics Problem Solving Achievement Test (PPSAT). They were allowed to talk aloud. The problems were given one by one to the respondents. The respondents were instructed to provide full solutions to each problem on the test paper. No time limitation was given for the respondents to answer the problems, however if the respondents showed impasse in their work, it was suggested that they moved on to the next question. In the meantime, each of the respondents was videotaped. Interviews were conducted right after the test. During the interview, the respondents' written answer to each of the problems was shown and the respondents were asked to discuss their recollection of their thinking while solving that problem. The total score were calculated and changed to a percentage (%). The highest score among participants was 75.7% and the lowest score was 13.5% (see Table 2). In any performance test on Malaysian examination usually, those who achieved less than 40% are considered weak and very weak. There are five levels of proficiency; excellent, good medium, weak and very weak (see Table 1).

**Table 1: Range of grades for determining the level of achievement in Malaysia examination**

| Range of Marks (%) | Level of achievement |
|---|---|
| 80-100 | Excellent |
| 60-79 | Good |
| 40-59 | Moderate |
| 20-39 | Weak |
| 0-19 | Very Weak |

Based on these preferences, 40% was chosen as the cut-off for differentiating between "more successful" and "less successful." Participants were then assigned accordingly. It was anticipated that not all participants would fall neatly into one of these two groups: Eight participants were classified as "more successful" and 13 participants categorized as "less successful" (Table 2).

**Table 2: Classification of more successful and less successful students**

| No. | Name | Field-work | Scores (%) | Age | Gender | Rating |
|---|---|---|---|---|---|---|
| 1. | Adam | 2 | 75.7 | 20 | M | More successful |
| 2. | Emma | 1 | 62.2 | 23 | F | More successful |
| 3. | Ruby | 1 | 59.5 | 23 | F | More successful |
| 4. | Isabelle | 2 | 48.6 | 23 | F | More successful |
| 5. | Thalia | 1 | 48.6 | 23 | F | More successful |
| 6. | Student a | 1 | 48.6 | 23 | M | More successful |
| 7. | Student b | 1 | 43.2 | 23 | F | More successful |
| 8. | Student c | 1 | 43.2 | 23 | F | More successful |
| 9. | Student d | 2 | 37.8 | 23 | M | Less successful |
| 10. | Student e | 2 | 35.1 | 21 | F | Less successful |
| 11. | Student f | 2 | 29.7 | 23 | F | Less successful |
| 12. | Student g | 2 | 27.0 | 23 | F | Less successful |
| 13. | Student h | 1 | 24.3 | 23 | F | Less successful |
| 14. | James | 1 | 24.3 | 25 | M | Less successful |
| 15. | Student i | 2 | 24.3 | 20 | F | Less successful |
| 16. | Sophia | 1 | 21.6 | 23 | F | Less successful |
| 17. | Student j | 2 | 21.6 | 20 | F | Less successful |
| 18. | Georgia | 2 | 18.9 | 24 | F | Less successful |
| 19. | Jack | 1 | 13.5 | 20 | M | Less successful |
| 20. | Student k | 2 | 13.5 | 20 | F | Less successful |
| 21. | Olivia | 2 | 13.5 | 23 | F | Less successful |

The ten students selected were given pseudonyms as Emma, Ruby, Adam, Isabelle, Thalia, James, Olivia, Georgia, Sophia and Jack while their real identities were kept anonymous. As shown in Table 2, Ruby, Emma and Isabelle were chosen from the first fieldwork where they scored as top rank participants. Adam and Thalia were chosen from fieldwork 2 and were classified as top rank participants as well. Merging the scores of the participants from both fieldworks resulted in, Adam, Ruby, Emma, Isabelle, and Thalia emerging as the top five scorers.

On the other hand, for the "less successful" participants, James, Sophia and Jack were chosen from the first fieldwork as the bottom participants from their scores. Georgia and Olivia were chosen later and they were classified as the bottom rank participants as well as from their score in the second fieldwork.

Each respondent's cooperation during the "thinking aloud" stage was also used in selecting the students. Especially used in selecting the less successful category, lack of cooperation such as not trying to solve the problems and simply withdrawing in answering the question.

## Findings and discussion

Members of both groups demonstrated aspects of monitoring in solving "lift" problem, but there were differences between the groups.

**Table 3: Monitoring and physics self-explanation by more and less successful**

| Metacognitive skills | More successful | Less successful |
|---|---|---|
| **Monitoring** | 13 | 19 |
| **Qualitative analysis** | 14 | 11 |

Based on table 3 above, less successful shows greater number of monitoring compared to more successful. On the other hand more successful shows greater number in qualitative analysis compared to less successful. Monitoring and qualitative analysis basically were interrelated. Based on this study, although less successful demonstrated higher monitoring but without a corresponding qualitative analysis it only produces "wheel spinning" and does not help the solver solved the problem successfully. This finding is supported by the study by Chi et al. (1989) who found similar results.

**Table 4: Comparison between more and less successful groups in monitoring and qualitative analysis**

| | More successful | | | | | Less successful | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Emma** | **Isabelle** | **Tahlia** | **Ruby** | **Adam** | **James** | **Georgia** | **Sophia** | **Jack** | **Olivia** |
| **Monitoring** | 6 | 1 | 1 | 4 | 1 | 4 | 4 | 6 | 3 | 2 |
| **Qualitative analysis** | 12 | 1 | 0 | 0 | 1 | 0 | 10 | 0 | 0 | 1 |
| **Grade for the "lift" problem** | 6/6 | 6/6 | 6/6 | 3/6 | 3/6 | 2/6 | 2/6 | 1/6 | 1/6 | 1/6 |

Georgia had as many monitoring responses as Ruby and almost as many qualitative analyses as Emma yet she did not get the lift problem. This is because she used the wrong mass and wrong equation. Although she produced a high number of monitoring and qualitative analyses, she failed to monitor and make qualitative analysis about which is the correct mass to use in the formula. She was supposed to used m=59 kg instead of 82 kg. She also used F=mg-ma, while the correct one was F-mg=ma. The numbers show lines from the whole transcripts that were coded as qualitative analysis and monitoring.

Based on table 4, almost every student shows monitoring during problem solving. However, an absence of qualitative analysis among the less successful causes them to fail in solving the "lift" problem. Apart from using monitoring to check understand or comprehension, it also helps solvers to always focus of the goal of the problem as well as to detect error. Some examples follow:

**Table 5: Example of monitoring**

| **Example of monitoring helps focus the goal of the problem** | |
|---|---|
| Emma (MS) | 21: so pecutan tak tau tu yang kita nak kira/ so the acceleration is unknown therefore that's what we need to calculate |
| Isabelle (MS) | 4: okay um apa yang perlu dicari/ Okay um what do I need to find<br>5: pecutan maksimum/ maximum acceleration<br>6: ok dia nak mencari nilai pecutan nilai a (tulis a =?) Okay i wants to look for the acceleration value a (writing a = ?) |
| Tahlia (MS) | 17: Dia suruh kira apa/ What does the question want me to find<br>18: Haha (ketawa)/ haha (laughing)<br>19: (baca soalan)/ reading the question<br>20: Baca alat ukuran penimbang berhati-hati. ketika lif berada pada tingkat 4, bacaan terbesar 82 (baca soalan)/ Look at the scale reading carefully. When lift is at the $4^{th}$ floor, the greatest reading was 82 (reading the question) |

| | |
|---|---|
| | 21: Ok dia nak pecutan/ Okay, the question ask about acceleration<br>22: Oh Pecutan (menggariskan soalan)/ Oh acceleration (underlined the question)<br>23: Curiga tentang pecutan maksimum/ wondering about the maximum acceleration<br>24: Oh ok ok faham faham/ Oh okay okay understood understood |
| Georgia (LS) | 67: macammana nak dapatkan pecutan maksimum/ how to find maximum acceleration |
| James (LS) | 53: so nak cari apa/ so what I need to find<br>54: haha/ haha (laughing)<br>55: saya tak tahu / I don't know |
| Olivia (LS) | 1: Hai..jadi/ so<br>2: Soalan dia apa/ what the question asked<br>3: Nak apa ni/ what is the question |
| **Example of monitoring helps students understanding** | |
| Adam (MS) | 4: Um / Um<br>5: Berat nak cari berat nak cari berat / weight need to find the weight need to find the weight<br>6: mg mg / mg mg<br>7: Macam mana ek (monitoring) / how (monitoring)<br>8: [...] / […]<br>9: (membaca soalan) / (reading the question) |
| Emma (MS) | 52: Um tiada maklumat yang membantu pun / Um there's no helpful information<br>53: T1 T2 bukan nak cari T sebenarnya (monitoring) / T1 T2 actually there's no need to find T (monitoring)<br>54: kejap / hang on<br>55: Anda curiga tentang pecutan (baca soalan) / You wonder about the acceleration (reading the question)<br>56: Tentang pecutan maksimum lif (garis maklumat pecutan maksimum pada soalan) / about the maximum acceleration for this lift (underlined the information on maximum acceleration in the question) |
| Isabelle (MS) | 17: um / um<br>18: F F (lihat persamaan) / F F (looking over the equation)<br>19: = mg / = mg<br>20: tambah / increase<br>21: berat dia bertambah (monitoring) / her weight increases (monitoring)<br>22: dia akan menjadi 820 N (menulis) (tulis rumus) / it become 820 N (writing) (writing down the formula)<br>23: ok / okay<br>24: so m dia adalah 82 (menulis) / so the m is 82 |

| Example of monitoring helps to avoid or detect error | |
|---|---|
| Isabelle (MS) | 24: so m dia adalah 82 (menulis) / so the m is 82<br>25: g dia 10 (menulis) / the g is 10 (writing)<br>26: a kita cari (menulis) (menulis maklumat drpd soalan) / we find a (writing) (writing down information from the question)<br>27: akan dapat 820 (menulis) / will get 820 (writing)<br>28: bukan 820 / not 820<br>29: oh no no silap kat sini (potong persamaan 82 (10+a) = 8 /oh no no it's incorrect here (crossed out the equation 82 (10+a) = 8)<br>30: m dia adalah 59 (menulis)(monitoring) / the m is 59 (writing) (monitoring)<br>31: g dia 10 (menulis) / the g is 10 (writing)<br>32: a dia yang perlu kita cari (menulis) (menulis maklumat drpd soalan) / it's the a that we need to find (writing) (writing down information from the question)<br>33: akan dapat sama dengan nilai 820 (menulis) / will get the same value as 820 (writing)<br>34: so di sini akan jadi um 590 + 59 a = 820 (menulis) / so here it'll become um 590 + 59 a = 820 (writing)<br>35: oleh itu 59a = 820-590 (menulis) / Therefore 59 a = 820-590 (writing) |
| Emma (MS) | 54: kejap / hang on<br>55: Anda curiga tentang pecutan (baca soalan) / You wonder about the acceleration (reading the question)<br>56: Tentang pecutan maksimum lif (garis maklumat pecutan maksimum pada soalan) / about the maximum acceleration for this lift (underlined the information on maximum acceleration in the question)<br>57: Maka anda buat keputusan untuk mengukur menggunakan penimbang (baca soalan) / Therefore you decided to measure using bathroom scale (reading the question)<br>58: Maksudnya bukan pecutan ni (potong a = 9.81)/ Which means this is not the acceleration (crossed out a = 9.81)<br>59: Kita tak tahu F F kita adalah ke atas F kita adalah sama T1 + T2 = ma So maksudnya T1 + T2 = ma (menulis) / We don't know F is F is going up F equal to T1 + T2 = ma So this means T1 + T2 = ma (writing) |

## Conclusions

Monitoring was shown to be an essential component of good problem solvers only when it is couples by effective qualitative analysis. This successful behaviour involves someone checking once again the veracity of their thought, concepts, calculations, equations, plans, diagrams or anything. They think back towards their understanding when they start the problem until they figure out their final answer and analyse the correctness of their process. It was thus shown that university students in physics that master this skill are successful problem solvers. The next phase of our work consists of teaching less successful students to acquire this skill.

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