The importance of metacognition in physics problem solving: Monitoring skills

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Abstract: The purpose of this paper is to show the importance of metacognitive skills in solving force and motion problem. This study consists of 10 students and students were divided into 2 groups based on their test score. One group were classified as more successful (MS) problem solvers and the other one as less successful (LS) problem solvers. Students solved physics problems while talking aloud. Each of the students were videotaped. Interviews were conducted right after the test. Written answers from physics task were marked according to the schema. In this paper, findings from one question were discussed. The question called "lift' problem. The thinking aloud were transcribed verbatim from the videotapes as well as interviews. Transcripts were coded and examined looking for both similarities and differences. As a conclusion, monitoring were shown as an important metacognitive skills in physics problem solving.

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

Introduction

Metacognition is 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 of experts and 5 of them as below are characters of metacognition:

(a) spending proportionately more time determining how to represent problems than they do in search for and in executing problems strategy
(b) developing sophisticated representations of problems, based on structural similarities among problems development of representations
(c) generally choosing a strategy based on elaborate schemas for problem strategies-selection of strategies
(d) accurately predicting the difficulty of solving particular problem-prediction difficulty
(e) carefully monitoring their own problem solving strategies and processes - monitoring

Such importance of metacognition in problem solving has also been stressed in many empirical studies. In physics problem solving study, Phang (2009) identified five metacognitive skills involved in problem solving processes among students studying Physics in the UK whose ages range from 14-19. These are monitoring, reflecting, regulating, evaluating and justifying. The importance of metacognition in problem solving as identified by Phang (2009) for example; monitoring and regulating students' memory and problem solving experience helps students to determine the level of difficulty of the problem; monitoring memory and experience in solving previous problems helps students to search for

the concept, knowledge and successful problem solving approach that was similar to the present problems; monitoring the concepts that might be related helps students to understand or solve the problem.

Chi et al., (1989) analysed self-explanation of good and poor problem solvers in physics as they studied example and solved problem. This study shows that actively and accurately monitoring their comprehension of the examples helps good problem solvers produced more self-explanations compared to poor problem solvers. Chi et al., (1989) refers self-explanation as ideas which says only something substantive about physics. Poor students show monitoring statement more than good students. However, good students produced greater number of physics explanation compared to poor students. Ferguson-Hessler and de Jong (1990) supported Chi et al., (1989) findings. According to them, by monitoring their comprehension helps good problem solvers produce more self-explanations and become better at detecting comprehension failures.

According to Larkin (1979), by using qualitative analysis, expert able to help reduces the chance of error because qualitative analysis is easy to check both against the original problem situation and against subsequently generated quantitative equations. According to Chi et al., (1989) by imply self-explanation in solving problem helps good problem solver to detect comprehension failure and understanding.

Research Objective

The purpose of this study is to identify the importance of monitoring skills in solving force and motion problem.

Research Question

What are the importance of monitoring skills in solving force and motion problem?

Background of the problem

Several studies show that lacking or absent metacognitive skills cause students failed in solving problems. For example, absence of consistent monitoring and regulating of the problem solving processes causes students do not solve the problem successfully (Artzt & Armour-Thomas, 1992; Biryukov, 2004; Foong, 1990; Kramarski, Mevarech, & Arami, 2002). According to Yimer and Ellerton (2006), without monitoring, students are less likely to take one of the many paths available to them and almost certainly are less likely to arrive at an elegant mathematical solution.

In contrast, a study by Sternberg (1998) showed how the presence of metacognition in problem solving lead experts to resolve geometry problems successfully. Experts manage to solve problems even though novices knew more about geometry. The reason experts arrived at successful solutions was because they utilised monitoring and regulation consistently when dealing with the problem (Sternberg, 1998).

From research, metacognition has been demonstrated as a factor that can enhance problem solving performance (Kramarski *et al.*, 2002; Özsoy & Ataman, 2009; Phang, 2009). The importance of metacognition in problem solving has been demonstrated by Heller (2002) to help students manage time and direction, determine next steps, monitor understanding, ask skeptical questions, and reflect on their own learning processes.

Davidson, Deuser, and Sternberg (1994) stated that metacognition helps the problem solver to see that there is a problem to be solved, work out what exactly the problem is, and understand how to reach the solution. Moreover, Fernandez, Hadaway, and Wilson (1994), stated that metacognitive skills like planning, monitoring and evaluating are important to manage problem solving strategies.

Methodology

This study consists of 10 students, which all had a physics background at the university level. All of the respondents solved four physics problems using physics pencil and paper test while talking aloud. The physics task were given name as Physics Problem Solving Achievement Test (PPSAT). The questions were given one by one to the respondents. The respondents were instructed to provide full solutions to each question on the test paper. No time limitation were given for the respondents to answer the questions, however if the respondents show impasse in their work, it was suggested that they move to the next question. In the meantime, each of the respondents were videotaped. Interviews were conducted right after the test. During the interview, the respondent's written answer to each of the problems were shown and the respondent were asked to discuss what they remember of their thinking when solving that problem. Table 1 are the scores obtained by each participating student on "lift" problems that consisted in this study:

Table 1: Score in physics task "lift"

No.	Name	Mark	Score	Rating
1.	Adam	3/6	50%	More successful
2.	Emma	6/6	100%	More successful
3.	Ruby	3/6	50%	More successful
4.	Isabelle	6/6	100%	More successful
5.	Tahlia	6/6	100%	More successful
6.	James	2/6	33%	Less successful
7.	Sophia	1/6	17%	Less successful
8.	Georgia	2/6	33%	Less successful
9.	Jack	1/6	17%	Less successful
10.	Olivia	1/6	17%	Less successful

Findings and discussion

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

Table 2: Monitoring and physics self-explanation by more and less successful

	More successful	Less successful
Monitoring	13	19
Analysis qualitative	14	11

Based on table 2 above, less successful shows greater number of monitoring compared to more successful. On the other hand more successful shows greater number in analysis qualitative compared to less successful. Monitoring and qualitative analysis basically were interrelated. Based on this study, although less successful demonstrated higher monitoring but without analysis qualitative does not help the solver solved the problem successfully. This finding also support the study by Chi *et al.* (1989) where similar result was found.

Table 3: Comparison between more and less successful in monitoring and analysis qualitative.

	More successful					Less successful				
	Adam	Emma	Isabelle	Tahlia	Ruby	Sophia	Olivia	Georgia	Jack	James
Monitoring	1	6	1	1	4	6	2	4	3	4
Analysis qualitative	1	12	1	0	0	0	1	10	0	0
Mark for "lift"	3/6	**6/6**	**6/6**	**6/6**	3/6	1/6	1/6	2/6	1/6	2/6

Based on table 3, almost every student shows monitoring during problem solving. However, lack of qualitative analysis among less successful causes them failed to solve "lift" problem.

Apart using monitoring to check understand or comprehension, finding also shows monitoring helps solvers to always focus of the goal of the problem as well as to detect error. Examples are as follows:

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
5: pecutan maksimum/ maximum acceleration
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
18: Haha (ketawa)/ haha (laughing)
19: (baca soalan)/ reading the question
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
22: Oh Pecutan (menggariskan soalan)/ Oh acceleration (underlined the question)
23: Curiga tentang pecutan maksimum/ wondering about the maximum acceleration
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
54: haha/ haha (laughing)
55: saya tak tahu / I don't know

Olivia (LS)

1: Hai..jadi/ so
2: Soalan dia apa/ what the question asked
3: Nak apa ni/ what is the question

Example of monitoring helps students understanding:

Adam (MS)

4: Um / Um
5: Berat nak cari berat nak cari berat / weight need to find the weight need to find the weight
6: mg mg / mg mg
7: Macam mana ek (monitoring) / how ek (monitoring)
8: [...] / […]
9: (membaca soalan) / (reading the question)

Emma (MS)

52: Um tiada maklumat yang membantu pun / Um there's no helpful information
53: T1 T2 bukan nak cari T sebenarnya (monitoring) / T1 T2 actually there's no need to find T (monitoring)

54: kejap / hang on
55: Anda curiga tentang pecutan (baca soalan) / You wonder about the acceleration (reading the question)
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
18: F F (lihat persamaan) / F F (looking over the equation)
19: = mg / = mg
20: tambah / increase
21: berat dia bertambah (monitoring) / her weight increases (monitoring)
22: dia akan menjadi 820 N (menulis) (tulis rumus) / it become 820 N (writing) (writing down the formula)
23: ok / okay
24: so m dia adalah 82 (menulis) / so the m is 82

Example of monitoring helps to avoid or detect error:

Isabelle (MS)

Reference 3

24: so m dia adalah 82 (menulis) / so the m is 82
25: g dia 10 (menulis) / the g is 10 (writing)
26: a kita cari (menulis) (menulis maklumat drpd soalan) / we find a (writing) (writing down information from the question)
27: akan dapat 820 (menulis) / will get 820 (writing)
28: bukan 820 / not 820
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)
30: m dia adalah 59 (menulis)(monitoring) / the m is 59 (writing) (monitoring)
31: g dia 10 (menulis) / the g is 10 (writing)
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)
33: akan dapat sama dengan nilai 820 (menulis) / will get the same value as 820 (writing)
34: so di sini akan jadi um 590 + 59 a = 820 (menulis) / so here it'll become um 590 + 59 a = 820 (writing)
35: oleh itu 59a = 820-590 (menulis) / Therefore 59 a = 820-590 (writing)

Emma (MS)

54: kejap / hang on
55: Anda curiga tentang pecutan (baca soalan) / You wonder about the acceleration (reading the question)
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)
57: Maka anda buat keputusan untuk mengukur menggunakan penimbang (baca soalan) / Therefore you decided to measure using bathroom scale (reading the question)
58: Maksudnya bukan pecutan ni (potong a = 9.81)/ Which means this is not the acceleration (crossed out a = 9.81)
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 in this study is referred to as checking of one's comprehension or understanding. The behaviour is called monitoring when someone checked once again of their thought, for example, concepts, calculations, equations, plans, diagrams or anything that makes them think back towards their understanding when they start the problem until they figure out their final answer. When the solvers monitored their understanding towards something, sometimes they will reread the question once again to clarify their thinking. Metacognitive skills of monitoring facilitate more successful focus of the goal of the problem, helps for more understanding and to avoid or repair errors during physics problem solving process.

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