THE INTERNATIONAL JOURNAL OF
HUMANITIES & SOCIAL STUDIES

Relationship between Dimension Metacognition and Students' Ability Level in Physics Problems Solving Involving the Use of Free-Body Diagram

Siti Nazirah Butai
Lecturer, Department of Preparatory Centre for Science and Technology,
University Malaysia Sabah, Malaysia
Fatin Aliah Phang
Associate Professor, Department of Faculty of Social Sciences and Humanities
University Technology Malaysia, Malaysia

Abstract:
Problem solving in Physics using Free-body Diagram (FBD) is complex and need to be planned carefully. Students who possess metacognitive awareness can make problem solving involving FBD easier. Therefore, this study aims at identifying the level of students' ability in solving physics problems involving the use of FBD and the student's metacognition as well as the relationship between all the dimensions in metacognition with their ability in solving physics problem. 300 Form 5 Science students from schools around Johor Bahru involved in this study. The data was collected using a set of instrument that includes paper-and-pencil test, known as Force Problem Solving Ability and Physics Metacognition Inventory (PMI). The findings show that the level of students' ability in solving physics problems involving the use of FBD was low, while the level of students' dimensions of metacognition was at a moderate level. The correlation analysis shows that a positively low and significant relationship between students' ability in solving physics problems involving the FBD with their dimension of metacognition. These findings suggest that teachers should emphasize thinking at the metacognition level among the students and to use different strategies in different physics problem solving.

Keywords: *Dimension metacognition, physics problem solving, free-body diagram, force problem solving ability*

1. Introduction

Problem solving is a basic part in the physics learning, besides it is an important matter that needs to be mastered by the students (Bahagian Pembangunan Kurikulum, 2012). Based on the thinking skills and thinking strategies model (TSTS), problem solving is one of the higher order thinking processes that involved critical and creative thinking skills (Bahagian Pembangunan Kurikulum, 2012). In physics education, the ability of students in problem solving is important because it is one of the ways to assess students' understanding and mastery of the physics learning (Balasubrahmanya & Merra, 2012; Joseph, 2010).

Besides, physics conceptual knowledge is crucial to help students in solving physics problems (Yap & Wong, 2007). According to Rosengrant et al. (2009), physics conceptual knowledge is usually represented in abstract symbolic form which is the delegation of every symbol that has an accurate meaning beside the combination with the correct strategies to use. Therefore, in physics problem solving, drawing free-body diagram (FBD) when solving physics problems is one of the strategies that used by students through making the meaningful symbols delegation (Nieminen et al., 2013). FBD drawing is usually used in solving Force problems. Force concepts involve an important relationships between the Newton movement and the concept that contains in the mechanic classic theory, which is taught since the secondary level (Nieminen et al., 2013).

According to Nieminen et al. (2013), physics problem solving involving the use of FBD is a complex problem solving that needs careful planning. This is because it is an ability to manage the abstract information, to ease students to solve harder problems with a variety of objects and interactions between forces involved. Therefore, the ability of physics problem solving involves FBD involves cognitive activities and metacognitive aspect based on the controlling thinking process and behavior that need to be taken during problem solving (Schellings et al., 2012; Taasoobshirazi & Farley, 2013b).

2. Metacognition in Physics Problem Solving Involving the Use of Free-Body Diagram

Researchers admit that problem solving involves a complex cognitive paradigm and non-routine experiences (Nokes et al., 2010; Phang & Seth, 2013; Ward, 2012). The problems usually occurred different an individual experienced the difficulty to solve it. This is because the answers needed in problem solving cannot be obtained immediately (Phang, 2009).

Besides, according to Zaidatun et al. (2008), the failure of students in problem solving is also due to infrequent questioning about choices of strategy that they use or making assessment whether the chosen strategy is effective or not. This is because students merely follow the instructions and complete the tasks without knowing why they need to do so and what they are doing. Furthermore, they also are unable to explain how they obtain the answers.

Therefore, metacognition is a critical factor in contributing to students' learning of physics (Lee et al., 2013). This is also supported by Hammouri (2003) who claimed that the success in problem solving needs the combination of process and strategy of two variables which are cognitive and metacognitive aspects. In addition, Taasoobshirazi & Farley (2013b) also explained that to be successful in problem solving especially involving FBD, students should have good thinking controlling strategy and need to be good in information management where both of strategies relate to the metacognition aspect. Thus, students should be given awareness about what they are doing, realize why they are doing so, and the mistakes that they are doing rather than the memorization of formulae and execution of mathematical algorithmic operations only.

Referring to Taasoobshirazi & Farley (2013b), students' metacognition in physics problem solving can be divided into six important dimensions, which are; i) Knowledge of cognition (declarative, procedural and conditional knowledge); ii) regulation of cognition in information management; iii) regulation of cognition in planning; iv) regulation of cognition in monitoring; v) regulation of cognition in evaluation; and vi) regulation of cognition in debugging. These six dimensions are not only important to the students, but also to teachers. Since teachers understand the students' metacognitive, they could help the students to excel in physics problem solving (Joseph, 2010; Seth et al., 2007; Taasoobshirazi & Farley, 2013a).

Therefore, the aim of this research is to identify the level of the students' ability in physics problem solving especially in solving problems that involve the use of FBD, besides to identify the dimensions of student' metacognition in physics problem solving. Thus, this research is not only important to students but also to teachers because it contributes to the improvement of teaching and learning process in the classroom especially in physics problem solving. Teachers are able to know and understand how the students' ability in physics problem solving and how the students apply metacognition during physics problem solving especially involving the use of FBD (Taasoobshirazi & Farley, 2013b). Students should realize and know how their minds function not only good in using formulae, but able explain and understand the concept in a particular physical system (Gok, 2010).

3. Methodology

This is a survey research that employs random sampling of 300 Form 5 science students around Johor Bahru chosen according to the sampling size by Krejcie & Morgan (1970). Every participant completed a set of instrument that consists of three sections - Section A, Section B and Section C. For Section A includes the information of respondent's demography. While Section B is a paper-and-pencil test known as Force Problem Solving Ability (FPSA) (Phang & Noor Izyan (2012) was adopted in this study. FPSA is using to collect information about the students' ability in physics problem solving involving the use of FBD. To analyze FPSA, every students need to solve the Force problem solving and the level of student ability in physics problem solving is determined by looking at the total number of correct items. The full mark for FPSA is 25 marks and is converted to percent as shown in Table 1.

Level of Ability	High	Moderate	Low
Number of correct items	17.5 – 25.0	10.0 – 17.3	0 – 9.8
Range of marks (%)	70 - 100	40 - 69	0 - 39

Table 1: Level of Physics Problem Solving Ability

Section C is Physics Metacognition Inventory (PMI) which has 26 items adopted from Taasoobshirazi & Farley (2013b). To assess the knowledge about students' metacognition in physics problem solving involving the use of FBD that uses 5-point scale ranging from never true of myself (1) to always true of myself (5). Table 2 shows the mean score of Dimension of Metacognition Level to be obtained. All these three sections were administered simultaneously as a set of research instrument and run for 1 hour and 30 minutes.

Level of Dimension	High	Moderate	Low
Mean score	3.68 – 5.00	2.33 – 3.67	1.00 – 2.32

Table 2: Level of Dimension of Metacognition in Physics Problem Solving

In addition, to the relationship between the two variables of ability in physics problem solving involving the use of FBD with dimensions of student' metacognition in physics problem solving was identified through Pearson correlation test, r (Asuero et al., 2006). Table 3 shows the meaning of the correlation Pearson r to be obtained too.

Value	Interpretation
0.00 - 0.29	Little if any
0.30 - 0.49	Low
0.50 - 0.69	Moderate
0.70 - 1.89	High
0.90 - 1.00	Very high

Table 3: Classification of Correlation Value

4. Results and Discussion

SPSS was used to obtain the percentage, frequencies, means, standard deviations and Pearson correlation value, r. The discussion begins by analyzing the levels of physics problem solving ability measured by FPSA, followed by the level of students' metacognition in physics problems solving in FBD and the relationship between the two variables.

4.1. Analysis Level of Physics Problem Solving Ability

Table 4 shows the analysis of the finding of FPSA.

Variable	Mean	Standard Deviation	Level
Physics Problem Solving	19.04	19.413	Lower

Table 4: Level of Physics Problem Solving Ability among form 5 Science Students in Secondary Schools around Johor Bahru

Refer to Table 4, the students' mean score in FPSA is 19.04, with standard deviation of 19.413.This shows the students' ability level in physics problem solving involving the use of FBD is at lower level, besides the difference distribution for the ability level of every student in physics problem solving has a huge amount. Therefore, the research finding shows that the students are unable to manage abstract information (Taasoobshirazi & Farley, 2013b). This is because the forces that interact on the objects is in an abstract form. Thus, by drawing FBD, the forces that interact can be seen clearly and indirectly, making it easier to answer the given problem solving questions. This could be seen through one of the examples of student's answer in FPSA who scored a high mark. The student used FBD to solve the problems. With the help of the Forces drawing that act on the object, the students were able to answer the problem easily and accurately. On the other hand, students that obtained lower mark in FPSA, FBD was not used to solve the problems. In addition, physics problem solving that involved the use of FBD is complex problem solving because of the variety of objects and the interactions between the involved forces.

Nevertheless, it is undeniable that the difficulty of students in problem solving is also depends on the individuals' knowledge and experience (Balasubrahmanya & Merra, 2012; Kohl & Finkelstein, 2008; Nokes et al., 2010). Therefore, the ability of the individual in problem solving is different whether that individual is categorized as an expert in problem solving or novice (Nokes et al., 2010). Thus, referring to the findings, the students are categorized as novices in physics problem solving especially in the use of FBD (Kohl & Finkelstein, 2008; Nieminen et al., 2013).

4.2. Analysis Dimension of Metacognition Level during Physics Problem Solving

Table 5 shows the analysis on mean score, standard deviation and the level of metacognition of the students. Overall, the students' metacognition is at a moderate level (mean = 3.35 and standard deviation = .632). However, the regulation of cognition in debugging is at a high level (mean = 4.04 and standard deviation = .885).This finding is aligned with the finding of Norzelina et al. (2011) that stated that students with moderate metacognition actually realized about why they do something, the mistakes they had done and try to improvise it when needed. Nevertheless, with this awareness, it is still unable to ensure the success in physics problem solving. This is clearly shown in the FPSA results where the students' ability problem solving is low. This means that there were some students who did not know how to choose the best strategy to solve problems that involve Forces.

Dimension of Metacognition	Mean	Standard Deviation	Level
Knowledge of cognition: Declarative, procedural, and conditional	3.07	.774	Moderate
Regulation of Cognition: Planning	3.46	.698	Moderate
Regulation of Cognition: Information management	2.94	1.015	Moderate
Regulation of cognition: Monitoring	3.18	.818	Moderate
Regulation of cognition: Evaluation	3.60	.891	Moderate
Regulation of cognition: Debugging	4.04	.885	High

Table 5: Level of Dimensions of Metacognition in Physics Problem Solving among Form 5 Science Students in Secondary Schools around Johor Bahru

However, it is undeniable that metacognition contributes to the success of students in physics problem solving. This statement is supported by Mirzaei et al. (2012), where metacognition is an important mediator in identifying the success of students especially in physics learning. In addition, there is another research that reported that metacognition has positive effects on the student ability in physics problem solving (Sungur & Senler, 2009).

Referring to the Table 5, the finding shows the level of science students regulation of cognition in information management is at the moderate level, with mean score value of 2.94. Although this dimension is between the moderate ranges, if it is compared with the mean score values of regulation of cognition in information management like monitoring, evaluating, planning and debugging, it is found that regulation of cognition in information management has the lowest mean score value compared to the other regulation of cognition.

As explained by Taasoobshirazi & Farley (2013b), this information management is referred to the specific strategy that used by students to solve physics problems effectively. Therefore, this shows that the students are weak in choosing the correct strategy. The students should choose FBD as a specific strategy to help them to solve Force problems in order to obtain the solution easily, quickly and correctly.

Compare to the finding of regulation of cognition in debugging, the level is high. Besides, it is different with the research findings of Sungur & Senler (2009) who found that regulation of cognition in debugging is high. This dimension is directly affecting to the student achievement in any given assignment. However, Sungur & Senler (2009) only focused on the positive effects to the overall student's achievement, and did not take into account of students' ability in solving physics problem involving the use of FBD. This different finding result shows that not all the assignment or any problem solving can be solved easily without knowing the correct strategy. In addition, according to Sungur & Senler (2009), the positive surrounding practiced in a classroom is one of the factors that can encourage the awareness of students in regulation of cognition in debugging. One of the examples is the encouragement from the teachers so that students would participate and ask questions in classroom.

4.3. Correlation Analysis of Metacognition Physics Problem Solving Ability

Referring to the results in Table 6, the finding of this research shows that there is a weak but significant relationship between the students' metacognition and their ability in physics problem solving involved the use of FBD ($r = .374$, $p = .05$).

Variables	Mean	Standard Deviation	r	Sig.
Physics Problem Solving	19.04	19.413	.374	.000
Dimension of Metacognition	3.35	.632		

Table 6: Pearson Correlation of Physics Problem Solving Ability between All the Dimensions of Metacognition among form 5 Science Students in Secondary Schools around Johor Bahru

This finding is synchronized with the research of Seth et al. (2007), where there is a low and significant positive relationship between metacognitive skills and physics problem solving. According to Norzelina et al. (2011), this is because the students' metacognition unable to help them to understand the physics concepts that can lead to the solution. Therefore, the students should have strong conceptual understanding and understanding in the strategies of the physics problem solving, such as the strategy to draw FDB to solve Force problems.

The significant relationship suggests that teachers need to encourage the awareness among students on their thinking process by helping them to monitor and control their own cognition using metacognition. By doing so, it develops the students to become experts in physics problem solving by practicing the characteristics such as setting the goal, analyzing the assignment carefully, always doing the monitoring on the result and doing the strategy evaluation systematically (Balasubrahmanya & Merra, 2012; Jausovec, 2011; Sungur & Senler, 2009).

5. Conclusion

The findings shows that there is a significant relationship between the dimensions of metacognition with the ability of physics problem solving that involved the using of FBD among the Form 5 Science students around Johor Bahru. Therefore, attention should be paid on developing metacognitive skills among the students. The analysis on students' results indicates that they were weak in solving physics problem that involve the FBD, while the level of students' metacognition as an overall was moderate. Therefore, it is important for each student to know the effective strategies that they can use to help them in solving physics problems especially those that involve Force. Students need to be experts in the use of FBD so that it can help them to be more successful in abstract problem solving (Phang & Noor Izyan, 2012). Moreover, the use of metacognition is seen as very important to be practiced especially during problem solving (Phang & Seth, 2013).

Besides, through this research, teachers know the importance to take into account of every step carried out by the students during problem solving. The teachers need to know and emphasize on how the dimensions of metacognition work and see how far the students' awareness on that dimensions of metacognition during physics problem solving. That knowledge is important to help the teachers improve and enhance the related teaching and learning process whether in building the teaching module or change the pattern of teaching in classroom (Malone, 2008; Taasoobshirazi & Farley, 2013a). It can also ease the teachers in planning the accurate teaching method based on the students' dimensions of metacognition by emphasizing the effect of each dimension during problem solving.

As a conclusion, through this research, it can be explained that the success of students in physics problem solving is not only depending on good knowledge in physics concepts but also support of the dimensions of metacognition awareness.

6. Acknowledgments

The authors would like to acknowledge the support of Faculty of Education, Universiti Teknologi Malaysia, Johor Bahru, Malaysia in conducting this study.

7. References

i. Asuero, a. G., Sayago, a., & González, a. G. (2006). The Correlation Coefficient: An Overview. Critical Reviews in Analytical Chemistry, 36(1), 41–59.
ii. Bahagian Pembangunan Kurikulum. (2012). Spesifikasi Kurikulum Fizik Tingkatan 4. Putrajaya: Kementerian Pelajaran Malaysia.
iii. Balasubrahmanya, H., & Merra, B. . (2012). How do they solve it ? An insight into the learner ' s approach to the mechanism of physics problem solving. Physical Review Special Topics - Physics Education Research, 8(1), 1–9
iv. Gok, T. (2010). The General Assessment of Problem Solving Processes and Metacognition in Physics Education. Eurasian Journal of Physics and Chemistry Education, 2(2), 110–122.
v. Hammouri, H. A. M. (2003). An investigation of undergraduates' transformational problem solving strategies: cognitive/metacognitive processes as predictors of holistic/analytic strategies. Assessment & Evaluation in Higher Education, 28(6), 571–586.
vi. Jausovec, N. (2011). Metacognition. Maribor: Elsevier Inc. 107-112
vii. Joseph, N. (2010). Metacognition Needed : Teaching Middle and High School Students to Develop Strategic. In Alternative Education for Children and Youth (Vol. 54, pp. 99–103). London: Heldref Publication.
viii. Kohl, P., & Finkelstein, N. (2008). Patterns of multiple representation use by experts and novices during physics problem solving. Physical Review Special Topics Physics Education Research, 4(1), 1–13.
ix. Krejcie, R. V, & Morgan, D. W. (1970). Determining Sample size for Research Activities. Educational and Psychological Measurement, 30, 607–610.
x. Lee, H. M., Chuang, C. P., Li, J., & Huang, Y. C. (2013). A Study on the Relation between Meta-cognition and Problem Solving Ability among the Students of Mechanical Engineering. Applied Mechanics and Materials, 266, 3439–3443.
xi. Malone, K. (2008). Correlations among knowledge structures, force concept inventory, and problem-solving behaviors. Physical Review Special Topics - Physics Education Research, 4(2), 20107.
xii. Mirzaei, F., Phang, F. A., Sulaiman, S., & Kashefi, H. (2012). Mastery goals, performance goals, students' belief and academic success : metacognition as a mediator. Procedia - Social and Behavioral Sciences, 46(2012), 3603–3608.
xiii. Nieminen, P., Viiri, J., Asko, M., & Antti, S. (2013). Does using a visual-representation tool foster students ' ability to identify forces and construct free-body diagrams ? Physical Review Special Topics - Physics Education Research, 9(10104), 1–11.
xiv. Nokes, T. J., Schunn, C. D., & Chi, M. T. H. (2010). Problem Solving and Human Expertise. International Journal of Science Education, 5, 265–272.
xv. Norzelina, I., Saniah, S., & Nor Hasnida, G. (2011). Kesedaran metakognisi dan pemahaman konsep dalam penyelesaian masalah matematik. In National Academic Conference (ENRICH 2011). 18-19 June. Universiti Teknologi Mara Kelantan, 1-9.
xvi. Phang, F. A. (2009). The patterns of Physics Problem-solving from the perspective of metacognition". University of Cambridge, UK.
xvii. Phang, F. A., & Noor Izyan, S. (2012). Pengajaran Free-Body Diagram (FBD) dalam menyelesaikan masalah tajuk daya Tingkatan Empat. In Seminar Majlis Dekan Pendidikan IPTA 2012. 7-9 October. The Zon Regency, Johor Bahru, Johor, 1-15.
xviii. Phang, F. A., & Seth, S. (2013). Metacognition and Science Education, 51–80. Unpublished.
xix. Rosengrant, D., Van Heuvelen, A., & Etkina, E. (2009). Do students use and understand free-body diagrams? Physical Review Special Topics - Physics Education Research, 5(1), 10108.
xx. Schellings, G. L. M., Hout-Wolters, B. H. a. M., Veenman, M. V. J., & Meijer, J. (2012). Assessing metacognitive activities: the in-depth comparison of a task-specific questionnaire with think-aloud protocols. European Journal of Psychology of Education. The Netherlands: Springer.
xxi. Seth, S., Fatin, A. P., & Marlina, A. (2007). Kemahiran Metakognitif Dalam Kalangan Pelajar Sekolah Menengah di Negeri Johor Dalam Menyelesaikan Masalah Fizik (No. 75161). Johor. Retrieved from http://eprints.utm.my/4566/1/75161.pdf
xxii. Sungur, S., & Senler, B. (2009). Educational Research and Evaluation : An International Journal on Theory and Practice An analysis of Turkish high school students ' metacognition and motivation. Educational Research and Evaluation, 15(1), 37–41.
xxiii. Taasoobshirazi, G., & Farley, J. (2013a). A multivariate model of physics problem solving. Learning and Individual Differences, 24, 53–62.
xxiv. Taasoobshirazi, G., & Farley, J. (2013b). Construct Validation of the Physics Metacognition Inventory. International Journal of Science Education, 35(3), 447–459.

xxv. Ward, T. B. (2012). Problem Solving. In M. D. Mumford (Ed.), Handbook of Organizational Creativity (pp. 169–188). United States: Elsevier Inc.
xxvi. Yap, K. C., & Wong, C. L. (2007). Assessing Conceptual Learning from Quantitative Problem Solving of a Plane Mirror Problem. Physics Education, 42(1), 50–55.
xxvii. Zaidatun, T., Jamalludin, H., & Nur Wahida, Z. (2008). Tahap Kemahiran Metakognitif Pelajar Dalam Menyelesaikan Masalah Matematik. In Seminar Kebangsaan Pendidikan Sains dan Matematik. 11-12 October Johor, 1-11.