METACOGNITION IN PROBLEM SOLVING PROCESS OF ONE-DIMENSIONAL KINEMATICS AMONG PHYSICS PRE-SERVICE TEACHERS

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ABSTRACT

Issue about low physics problem solving performance in Indonesia due to lack of metacognitive skills urged the development of explicit instruction. This urgency has led to the need of deep understanding about students' metacognitive behaviour and how these behaviour affect the problem solving process. This study aims to identify metacognitive behaviour that students exhibited while solving one-dimensional kinematics problem and examined the role of metacognition in problem solving process of one-dimensional kinematics. A qualitative study was employed. Six students from Physics Education programme at a university was chosen as the participants in this study. Data were collected through think aloud method, observation, retrospective interview and answer sheet. The think aloud activity was recorded, transcribed and coded. Findings from think aloud analysis was supported by findings from analyses of observation, interview, and students' answer sheets. The findings reveals twelve metacognitive behaviours that exhibited by the students while solving one-dimensional kinematics problem which were rereading, reading with strategy, arrange the information, draw a sketch, making sense of the problem, relating the concept, speculating the answer, formulating the plan, breaking down the plan, assessing the plan, reflecting on the plan, and assessing the computation. The data findings also suggest three roles of metacognition in problem solving process of one-dimensional kinematics which were metacognition enables student to construct their understanding of the problem, regulate their action, and monitor their progress during problem solving. The findings of this study provided information to design the explicit metacognitive instruction which aimed to improve problem solving performance of students.

METAKOGNISI DALAM PROSES PENYELESAIAN MASALAH KINEMATIK SATU DIMENSI DI KALANGAN GURU PRA-PERKHIDMATAN FIZIK

ABSTRAK

Isu mengenai prestasi rendah dalam menyelesaikan masalah fizik di Indonesia kerana kurangnya kemahiran metakognitif menggesa pembangunan instruksi pembelajaran eksplisit. Cabaran ini telah membawa kepada keperluan pemahaman yang mendalam mengenai tingkah laku metakognitif pelajar dan bagaimana tingkah laku ini mempengaruhi proses penyelesaian masalah. Kajian ini bertujuan untuk mengenal pasti tingkah laku metakognitif yang dipamerkan pelajar semasa menyelesaikan masalah kinematik satu dimensi dan mengkaji peranan metakognisi dalam proses penyelesaian masalah kinematik satu dimensi. Kaedah kualitatif digunakan dalam kajian ini. Enam pelajar Program Pendidikan Fizik di universiti dipilih sebagai peserta dalam kajian ini. Data dikumpulkan melalui kaedah *think aloud*, pemerhatian, temu bual retrospektif dan lembaran jawapan. *Think aloud* aktiviti dirakam, transkripsikan dan dikodkan. Dapatan daripada analisis *think aloud* disokong oleh dapatan dari analisis pemerhatian, temu bual, dan lembaran jawapan pelajar. Hasil kajian mendedahkan duabelas tingkah laku metakognitif yang dipamerkan oleh pelajar semasa menyelesaikan masalah kinematik satu dimensi yang mana, membaca semula, membaca dengan strategi, menyusun maklumat, melukis gambar, memahami masalah, mengaitkan konsep, membuat spekulasi mengenai jawapan, merumuskan rancangan, membahagi rancangan, menilai rancangan, mengubahsuai rancangan, dan menilai pengiraan. Dapatan kajian juga mencadangkan tiga peranan metakognisi dalam proses penyelesaian masalah

kinematik satu dimensi yang mana metakognisi membolehkan pelajar membina pemahaman mereka tentang soalan, mengawal tindakan mereka, dan mengawasi kemajuan mereka semasa menyelesaikan masalah. Penemuan kajian ini akan memberikan maklumat untuk merekabentuk instruksi pembelajaran metakognitif eksplisit yang bertujuan untuk meningkatkan prestasi menyelesaikan masalah pelajar.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Metacognition has become an issue of educational research in the last three decades (Son, 2013; Zohar & Barzilai, 2013) and has been linked to improving students' learning (Macaro & Erler, 2008). Result of various influential researches even shows that applying metacognition in school increases student's performance (Perry, 2018). Recently, an educational organisation the Partnership for 21st Century Skills claimed metacognition is a necessary skill to acquire for students' carrier and life-time (Lai, 2011).

Metacognition is -as John Flavel, the psychologist who introduced the term defined it- "one's knowledge concerning one's cognitive processes or anything related to them" (Flavel, 1979) such as the data or information of learning-relevant. An individual will be considered engaging in metacognition if s/he notices that learning C is more difficult than learning D or if s/he notices s/he should check her answer before submits it (Flavel, 1979).

Lee and Mak (2018) believed that metacognition gives a student an understanding of her strengths and weaknesses, and use such understanding to improve her learning. If students know their strengths and weaknesses in learning, they will be more engaged in their learning activity, such as to monitor their strategy and resources of learning, assess their preparedness for tasks and performances (Bransford, Brown, & Cocking: 2000). It will be likely that students who develop metacognition will be successful learner than students' who do not. Therefore, metacognition considered as a decisive aspect of successful learning as many studies encourage the use of metacognition in schools. Researchers and scholars in the educational field highly suggest to embrace metacognition as a crucial component of methods for teaching and learning in the various area such as reading, problem solving, writing and high order thinking (Zohar & Barzilai, 2013).

Since 1980 metacognition emerged as a key factor for prediction of problem solving performance (Teong, 2000). Metacognition is related to students' awareness of their ability to develop various ways to solve the problem. According to Panaoura, Philippou, & Christou (2003) students who have high metacognitive ability are better problem solvers because they able to analyse their strategies while solving the problem and evaluate on it then decide if they need to modify or choose another strategy to get the right answer.

Previous researches have proved that metacognition plays a big role in problem solving performance (Schoenfeld, 1992; Foong, 1993; Yeap, 1998; Kapa, 2001; Phang, 2006, 2009; Kuzzle, 2011, Zhang, 2014). Research on metacognition in problem solving started in the area of mathematics problem solving (Schoenfeld, 1985). Schoenfeld (1985; 1987; 1992) who conducted studies on metacognition in mathematical problem solving argued that deficiencies in metacognitive aspects are a fundamental cause of students' failures when solving problems. Schoenfeld's studies have shown that when students have sufficient content knowledge to solve a problem, they may still fail to do so because they lack suitable metacognitive control to select, continue, or abandon a specific strategy. Schoenfeld (1985) noted that students who lack problem solving skills, often perform meaningless calculations without giving much thought to the problem, solve problems without any planning and evaluating of their problem solving approach, and give up easily if the problem is not solved in a short time as a result of emotions such as frustration. Therefore, Schoenfeld argued metacognition plays a crucial role in the problem solving process.

Since then, numerous scholars and researchers have conducted studies regarded the role of metacognition in problem solving (e.g., Garofalo & Lester, 1985; Schoenfeld, 1992; Phang, 2006; Phang, 2009; Kuzle, 2011, Zhang, 2014) not only in mathematics but science fields as well such as biology, chemistry, and physics. In physics problem solving, metacognition helps pupils identify and define the problems; and plan how to proceed with the plan how to solve the problem (Soesilawaty, Saefudin, Wulan, and Adianto, 2019). However, studies about metacognition process in Physics problem solving are still limited especially the study that focused on problem solving in one specific topic of Physics. Research on metacognition in physics education is less frequent in the literature than it is in chemistry and/or biology education (Thomas, 2013). Therefore, the present study attempts to seek a better understanding of metacognition in Physics problem solving process especially in one particular topic, one-dimensional kinematics which is recognised as the first topics that are taught in physics classrooms. The findings of this study may render suggestions for metacognitive training to improve problem solving in one-dimensional kinematics topic.

1.2 Background of the Study

Veenman (2012) believed that one of the main focus of research on metacognition in science education is metacognition on problem solving. It is reasonable as developing students' proficiency in problem solving has long been recognized as one of the main objectives in educational fields especially science education (Adeoye, 2010; Lorenzo, 2005). Physics as an elemental science that has dominant problem-solving nature (Reddy & Panacharoensawad, 2017) is no exception.

Problem solving considered as a crucial part in Physics (Henderson, Heller, Heller, Kuo & Yerushalmi, 2001). It facilitates students' how to learn the concepts and related one concept to other concepts. During school and college year, students' work in class, homework or test involves solving the problems. Moreover, mastering problem solving helps students develops an applicable skill in solving problems in real-life situations. Thus, graduates from physics degrees are expected to be proficient in solving problems.

Metacognition supports in problem solving has been widely proven through various studies (Schoenfeld, 1992; Foong, 1993; Yeap, 1998; Kapa, 2001; Phang, 2006, 2009; Kuzzle, 2011, Zhang, 2014). According to Wang & Chiew (2010) problem solving is one of the fundamental human cognitive processes, while as explained before metacognition is individuals' awareness about their cognitive process and being able to organize this process. Thus, it is reasonable if metacognition plays a key role in problem solving. Metacognition and problem solving are interrelated. While metacognition is an important dimension of problem solving (Gardner, 1991; Karmiloff-Smith, 1992) problem solving activities are also ideal opportunities to enhance metacognitive strategies (Du Toit & Kotze, 2009). Gartman & Freiberg (1993) believed that the main purpose of teaching problem solving to students is not only to provide them with a set of skills but also allow students to think about what they think. The part 'think about think' in problem solving is what we called metacognition. Previous researches have been conducted to ascertain the role of metacognition during problem solving. Most of the research begins with the identification of aspects of the student's behaviour in which metacognition are likely to be present. Findings of these researches were framework or model into which metacognition can be incorporated (Yimer & Ellerton, 2009). One of the first studies on the role of metacognition in problem solving was a project by Lester, Garofalo, & Kroll (1989). Lester, Garofalo, and Kroll (1989) studied the role of metacognition in problem solving. They conducted both qualitative and quantitative analysis of students' metacognitive behaviours and the effect of metacognitive instruction. Results revealed that the more successful problem-solvers were better able to monitor and regulate their problem-solving activity than were the poorer problem solvers. Good problem solvers tended to develop a meaningful sense about the conditions and questions of the problems, whereas poor problem solvers tended to be content with superficial understanding. Yimer (2004) argued there are few behaviours that inherent characteristics of metacognition while solving a problem such as analysing the information in the problem, then organizing them from one's knowledge store, devising a plan of attack, and evaluating all processes. These behaviours are important to perform successful problem solving (Yimer, 2004).

Despite the acknowledgement of the importance of metacognition in Physics problem solving, studies about metacognition process in Physics problem solving are limited. Research on metacognition in physics education is less frequent in the literature than it is in chemistry and/or biology education (Thomas, 2013). In Indonesia, a few authors have done researches on metacognition in physics problem solving process but not particularly regarding one topic in physics. Moreover, most of the investigations and intervention of metacognition in learning and teaching science have concentrated on secondary schools students, but not many studies focused on university students especially students in Physics teacher training program. Therefore, the present study attempts to seek a better understanding of metacognition in problem solving process of one-dimensional kinematics by identifying the problem solving steps and metacognitive behaviour of Physics Education students while solving one-dimensional kinematics problem and examine the role of metacognition in problem solving process of one-dimensional kinematics. The findings of this study may render suggestions for metacognitive training to improve problem solving performance.

This study will focus on one particular topic of Physics: one-dimensional kinematics. The reason of why this study only focus on one small area of Physics because metacognition is concept-independent (Zhang, 2014), means if an individual is given the two question from a different topic, the individual may exhibit very different metacognitive behaviours while solving these two problems. Lester (1994) also draws out that to teach students to be more cognisant of their cognitive process during problem solving and being able to monitor their acts should begin with specific concepts of domain subject. One-dimensional kinematics is chosen not because there is a specific case found while students solve the problem in this topic, but this topic is the first topics introduced in most introductory physics classrooms throughout every educational stage due to the major ideas in these units, position, velocity, and acceleration, are incorporated into almost all other topics in physics (Manurung & Mihardi, 2016). Without a solid problem solving skill in this important topic, students lack the foundation necessary to succeed in Physics (Archambault, Burch, Crofton, McClure, 2008). The finding of this study intended to provide a data point for the development of explicit training and teaching of metacognition to improve problem solving performance in one-dimensional kinematics topic.

1.3 Statement of the Problem

In Indonesia, the demand for problem solving skill and metacognitive skill can be seen from the education policy. According to the implemented curriculum, problem solving skill and metacognitive skill become standard that needs to be achieved by every graduate in all level of education in Indonesia (Kemendikbud, 2016) including university students in Physics teacher training program. These students as prospective Physics teachers in the senior level must be proficient in problem solving and have a sufficient metacognitive skill to utilize it in the future (Mataka, Cobern, Grunert, Mutambuki, & Akom, 2014). Later, these students will hold a responsibility to teach those skill to their students.

However, researches reported that students in teacher training program showed poor performance in Physics problem solving (Siswono, Kohar, Kurniasari & Astuti, 2016; Sutarno, Setiawan, Karniawati, & Suhandi, 2017; Fitriyanto, Yahya & Walidain, 2018; Zainuddin, 2018). Sutarno et al. (2017) who conducted a study about the skills of pre-service physics teachers' in employing strategies during problem solving process in Indonesia found that they lack problem-solving skills. They reported that the pre-service teachers could not understand the problem completely, their understanding of the problem is split into pieces, they could not relate one concept with other concepts, and they tend to rely on the information that is given in the problem as their resources (Sutarno et al., 2017).

In the previous study about problem solving, Siswono et. al. (2016) already stated that majority of the pre-service teacher weakness in problem solving is not coming from lack of content knowledge rather lack of sense in choosing the effective problem solving strategy and assessing their strategy which those skills are related to metacognition. As Panaoura, Philippou, & Christou (2003) stated metacognitive skill make students able to analyse their strategy while solving a problem and evaluate their strategy to decide to modify or choose another strategy. Paralleled with Siswono's report, Azizah and Nasruddin (2018) who studied about the empowerment of metacognitive skills found that students in the teacher training program demonstrated very little metacognitive skills during problem solving. They also found the reason behind the lack of presence of metacognitive skills in the classroom. They stated that teachers do not train their students to use metacognition in solving problems due to the difficulties in empowering metacognitive skills. Furthermore, they added that the difficulties rose because metacognition is an abstract activity in one's mind so that it cannot be observed directly even though it can happen at any time and students do not spontaneously engage in metacognitive thinking and skills. Another report from Arias (2017) also found that knowledge and practices of metacognition are not commonly found in the university classrooms.

Lee, Teo, and Bergin (2009) already stated that metacognition is an important aspect in the problem solving process; however, an effective way to enhance metacognitive skill in the classroom is remaining a challenge. It was because metacognition is a mental activity. Thus, empowering metacognition is not enough only with teaching the students 'what is metacognition', teachers need to teach their students how to behave metacognitively while solving a problem (Matene, 2018). This means that teaching metacognition to students to improve their problem solving skill requires explicit instruction. Developing the design of explicit instruction that empower metacognitive skills in problem solving is a crucial undertaking.

Explicit instruction means teachers should model the processes during problem solving and metacognitive activity so that students can see it in action (Arias, 2017). These processes involve problem solving steps and metacognitive behaviour that students should do to carry out successful problem solving. Embedded metacognition in the curriculum and emphasising it through explicit instruction in the classroom in the teacher education program has been suggested by Arias (2017) to develop students' metacognitive and problem solving skills. This is also supported by Hartman (2001), he said that students' metacognitive and problem solving skills can be improved through explicit instruction.

Developing explicit instruction that involves metacognitive activity to improve problem solving means more information about metacognitive activity and how they support problem solving is needed. As Wilson and Clarke (2004) argued that to optimise students' metacognitive activity, the teacher will need the information about those metacognitive activities and how it supports the student.

Hence, this research is conducted. This research has been designed to look into students' problem solving process in which students engage while solving one-dimensional kinematics problem and identify the metacognitive behaviour that student exhibits while solving one-dimensional kinematics problems, then examine the role of metacognition in problem solving process of one-dimensional kinematics. This is a crucial initial step in designing explicit instruction. Phang (2009) stated in her dissertation, developing instruction to improve problem solving and metacognitive skills is not an instant process, the fundamental preconception of the students' behaviour during problem solving should not be ignored. Because designing an instruction to improve problem solving performance requires the understanding of how students address the problems and how they work with problems in the first place. The findings of this study intended to provide a data point for the development of explicit training and teaching of metacognition to improve problem solving performance in one-dimensional kinematics topic.

1.4 Research Objectives

This research has two objectives, they are:

1. To identify metacognitive behaviours that student exhibits while solving one-dimensional kinematics problem.
2. To examine the role of metacognition in problem solving process of one-dimensional kinematics

1.5 Research Questions

In order to answer the research problems, the researcher posed these following research questions:

1. What are metacognitive behaviours that students exhibit while solving one-dimensional kinematics problem?
2. What is the role of metacognition in problem solving process of one-dimensional kinematics?

1.6 Significance of the Study

As a qualitative study, this study did not plan to generalize the finding. The broad aim of this study is to develop a better understanding of metacognition in problem solving process of one-dimensional kinematics by identifying the problem solving steps that students use to solve one-dimensional kinematics problem and metacognitive behaviour that student exhibits while solving one-dimensional kinematics problems, then examining the role of metacognition in problem solving process of one-dimensional kinematics. The finding of this study should further add to the growing bank of theory and research that has focused on metacognition in one-dimensional kinematics problem solving process. The findings of this study also will add information to design the explicit metacognitive instruction which aimed to improve problem solving performance of students. According to Wallace (2014) by gaining an insight into student thought process and behaviour while solving a physics problem, we can clarify students' weakness areas and potentially provide better instructional strategies to improve these contexts.

For the Physics Education students who participated, it was determined whether this activity was regarded as beneficial. It could become a testimony of sorts to their growth as a prospective teacher and a learner as well. For Physics lecturer, the finding of this study will add information about students' metacognition in physics problem solving as a reflection or guide mechanism for teaching Physics problem solving. For the university, the narratives generated by this study could help further their understanding of students metacognition in one-dimensional kinematics problem solving and possibly influencing instructional development.

For teacher education programs, the study also provides recommendations for future, especially Physics Education program to promote a better understanding of metacognition while preparing Physics teachers. As educational policy becomes increasingly evidence-informed in the recent years (Perry, 2018), the findings of this study can be useful as a contribution to scientific literacy which can later be used as a basis for consideration in developing a curricular that related to metacognition in problem solving.

1.7 Limitation of the Study

Although the research is carefully prepared, there is an unavoidable limitation. In this study, the sample size will be considered as a limitation of the study. The samples are small and do not represent the majority of the students. Participants who were engaged in this study are confined to first-year students from Physics Education Department in one of University in Aceh. Therefore, the findings of this study which are metacognitive behaviour and its role in problem solving only applied to these samples. To generalize the result for larger groups, the study should have involved more participants at different levels. Another limitation is the metacognitive behaviours identified in this study are those that audible to the researcher as some of the participant's thoughts may not be verbalised during problem solving.

1.8 Definition of Term

1.8.1 Metacognition

Flavell (1979), who often considered being the father of metacognition, defined metacognition as one's knowledge about one's cognitive process or anything related to them. In this study we need to distinguish two words that will often appear in this study, metacognition is a verb that shows a process whereas metacognitive is an adjective that shows action or reaction that represents the characteristics of metacognition (Chairani, 2016). Metacognition in this study refers to students' awareness of their ability to develop various ways to solve the problem. While metacognitive behaviour refers to any action or reaction students made during problem solving that represents characteristic of metacognition such as the act to plan a strategy for approaching the problem, modify the strategy as needed, reflect on and evaluate results. According to Artzt & Armour-Thomas (1992), metacognitive behaviours could be found in solver's verbatim or behaviour during the problem solving process. The term 'role of metacognition' in this study refers to the function of the presence of metacognitive behaviour during the problem solving process.

1.8.2 Problem Solving

The act of solving a problem is called problem solving. The definition of problem solving is closely related with the existence of the problem itself because what is a problem for one may not be a real problem for another in that they can immediately see how to solve it. Mayer & Wittrock (2006) defined problem solving as a cognitive process of an individual accomplish one goal when the individual does not have an automatic method to reach that goal. In this research, problem solving refer to the process of decision-making when a student is given the problems which they do not have an automatic method to get the solution. Every individual has their own way to solve the problem, thus their behaviour or action during problem solving could be different for each student.

1.8.3 One-Dimensional Kinematics

Kinematics is part of mechanics, the study of motion in Physics. Kinematics is the first topics introduced in most introductory physics classrooms throughout the educational stage. Kinematics cover the topic about the motion, objects, and systems of objects without considering the forces as the one who causes the motion. While one-dimensional kinematics cover the small area in kinematics including position, velocity, acceleration and uniformly linear motion. In this study, the scope of problem solving only focused on one-dimensional kinematics topic, which means the problems given to participants cover the topic about the motion, objects, and systems of objects without considering the forces as the one who causes the motion in one dimension.

1.9 Summary

This chapter gives a brief explanation of the introduction of the study which begins with metacognition elaboration. The background of the study explains about metacognition and how metacognition contributes to problem solving process especially in science education including Physics. It followed by the statement of the problem that mentions that students in the teacher training program showed poor performance in Physics problem solving. Those weaknesses in problem solving are not coming from lack of content knowledge rather lack of metacognition skill and there is need explicit metacognition instruction to teach problem solving.

Therefore, this research aims to look into students' problem solving process in which students engage while solving one-dimensional kinematics problem and identify the metacognitive behaviour that student exhibits while solving one-dimensional kinematics problems, then examine the role of metacognition in problem solving process of one-dimensional kinematics. This is a crucial initial step in designing explicit instruction. To achieves the goal, the researcher formulates research objectives as well as research questions to specify the aim of this research. Furthermore, the concept of problem solving, metacognition, and previous studies described in the next chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of the Chapter

The chapter begins with literature reviews on how to define problem and problem solving. The following section discusses metacognition and its conceptualisation and the role of metacognition in learning particularly in problem solving. Then the chapter also includes the discussion about how to assess metacognition in problem solving, how to differentiate cognitive behaviour and metacognitive behaviour during problem solving, cognitive-metacognitive framework in problem solving from previous studies and research carried out in that area. At the end of the chapter, the theoretical framework and conceptual framework of this study are presented.

2.2 Problem and Problem Solving

Since this study will probe into problem solving, obviously defined the term "*problem*" is needed. In psychology, Hayes (1989) defined problem is "a situation where you found a gap between where you are and where you desired to be, and you do not know how to fill the gap." Furthermore, the implication of this definition is not absolute as each individual will view one task or situation differently. One person might view task A as a problem while a different person interacting with the same task might not find it to be a problem. An individual's knowledge and ability will affect the judgement if that individual view one situation as a problem. Bodner (2003) believed if she/he has an automatic solution for the question then the question is exercise. However, if the individual having a hard time to find the method to answer the question then the question is a problem for him/her. The clear identification of what task or situation are being used to bring out subject's interaction where he/she qualify task/situation as a problem is very important especially for research or study about thought process or metacognition of an individual during problem solving. If a task used is viewed as an exercise by the subject then it would be difficult to identify the subject's thought process or subject's metacognition ((Pressley & Afflerbach, 1995).

A problem consists of three components, first the initial state or *givens*, then the end state or *goal,* and the process to fill the gap between the initial state and the end state which stated as *operations* (Chi, Feltovich, & Glaser, 1981). However, the structure of problems can differ vastly. In educational settings, there are two types of problem structure which are frequently encountered.

The first type of problem is *Well-Structured Problems***.** In these type of problems, the givens and desired goal are clearly stated, means problem solvers has all information needed to solve the problem so they can use straightforward application of concepts or principles to reach the solution (Maloney, 2011). Well-structured problems are frequently appearing in standard textbooks. Second, *Ill-Structured Problems***.** Meanwhile, these types of problem have a vague desired goal, some absent necessary information and there might be several feasible solution paths. Usually, the situation in ill-structured problems emerge from real-life situations and they likely have "preferred" answer that involves the certain application of concepts and principles that related with one subject domain (Maloney, 2011). In this study, these two types of problem were used according to their respective function.

Problem solving itself can be defined as the act of solving a problem (Delvecchio, 2011) as it is closely related to the existence of the problem itself. Newell & Simon (1958) described problem solving as a process of decision-making when an individual is given a task which she/he do not have an automatic solution for the task. Martinez (1998) defined problem solving as “the process of moving toward a goal when the path to that goal is uncertain”. While Mayer and Whitrock (2006) description said problem solving is the cognitive process of an individual accomplish one goal when the individual does not have an automatic method to reach that goal.

Each of the definitions implies that problem solving is same as the problem. The process itself depends on the problem solver’s perception of the task/situation. Therefore, the selection of a question as a problem in this study will be based on the subject’s response to the question, rather than the question itself. If a question does not meet requirements as a problem for the subjects, then it becomes simply an exercise for them.

Problem solving is a linear, hierarchical process. There are different approaches to explaining problem solving processes. Psychologists and educationalists have identified a few steps or manoeuvres involved in the problem solving process that they claimed will result in successful problem solving. These steps are referred to as problem solving model.

The first problem solving model probably is the most mentioned in the literature, Polya’s model. Polya (1957) explained that there are four steps for solving problems in mathematical learning. First, understanding the problem. This step involves discover the information or *given* that presented in the problem, distinguish which information is relevant, arrange the important information or represent the information in symbol or picture. The second step is to devise a plan. In these steps, the solver comes up with an idea of how to connect the information in the problem and the goal desired in the problem. The third step, carry out the plan, the solver executes the plan to reach the goal. The last step is looking back, means the solver should check the result for correctness.

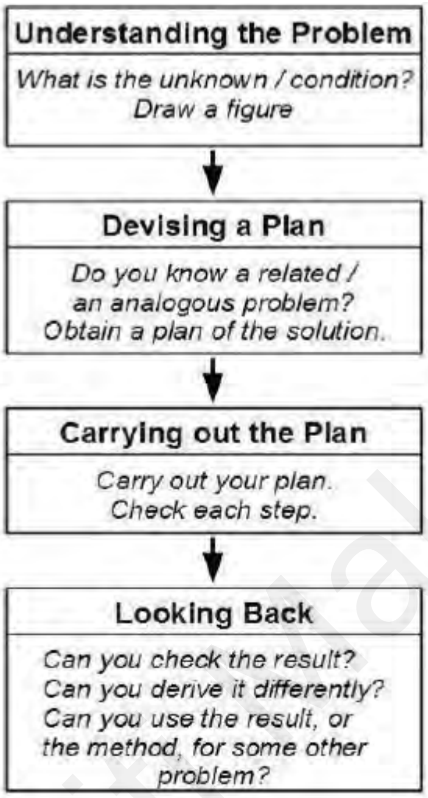


Figure 2.1 Polya's Problem Solving Model (Polya, 1957)

Years later Schoenfeld (1985) added the phase Exploration to the model of Polya (see Figure 2.4). Schoenfeld stated that "Exploration is the "heart" of the strategy. Schoenfeld's phase that composes of analysis, implementation, and verification are alike with Polya's step of problem solving.

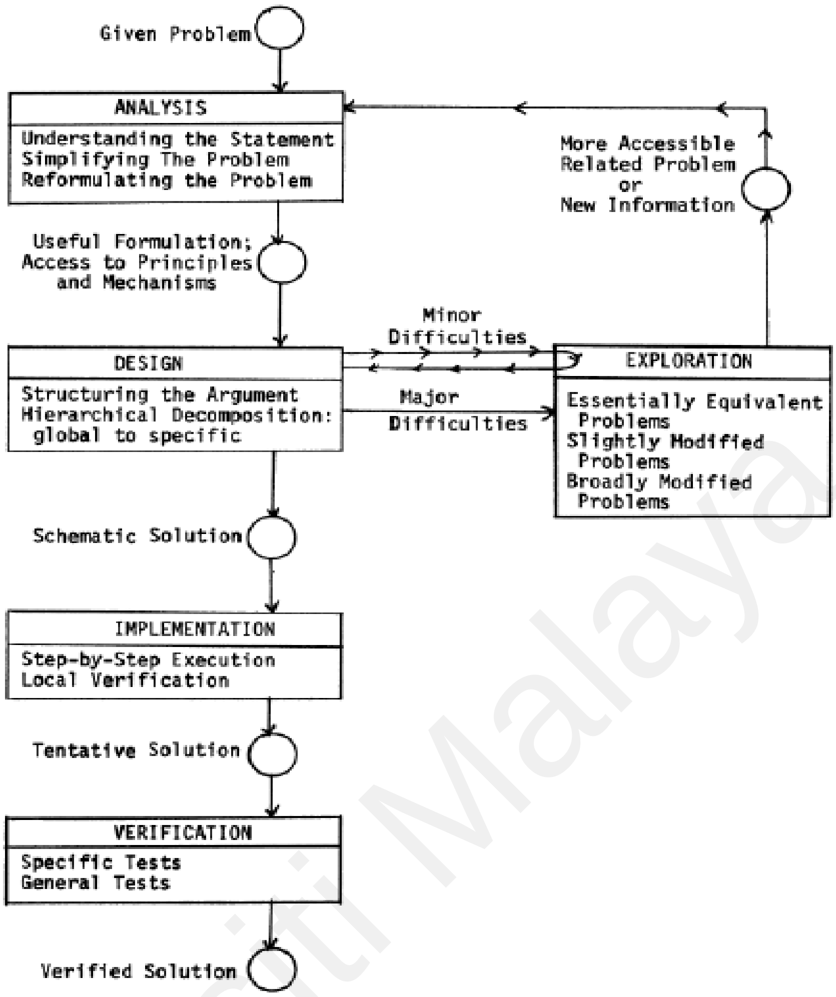


Figure 2.2 Schoenfeld's Problem Solving Model (Shcoenfeld, 1980)

Then Bodner (2003) offered problem solving models for chemistry problem solving which he claims promising more success for problems than Polya's method which is a more proper method for generic exercises. The model's that Bodner propose include: (1) read the problem, (2) read back the problem, (3) arrange the relevant information from the problem, (4) make a sketch or write the formula to help you, (5) attempt to do something, (6) make an attempt again, (7) see your result, (8) read back the problem, (9) try another attempt, (10) see your new result, (11) check your result if it is correct, (12) reread the problem, (13) if you fail, you are allowed to express your annoyance, (14) answer again, (15) check again, (16) repeat again if you have to or if you succeed then you can celebrate.

However, none of the models above aimed for Physics problem solving. Savage and William proposed the Systematic Modelling Method for algebraic mechanics topic for university student. They suggested solving a real-life problem. The systematic modelling method is as illustrated in Figure 2.4.

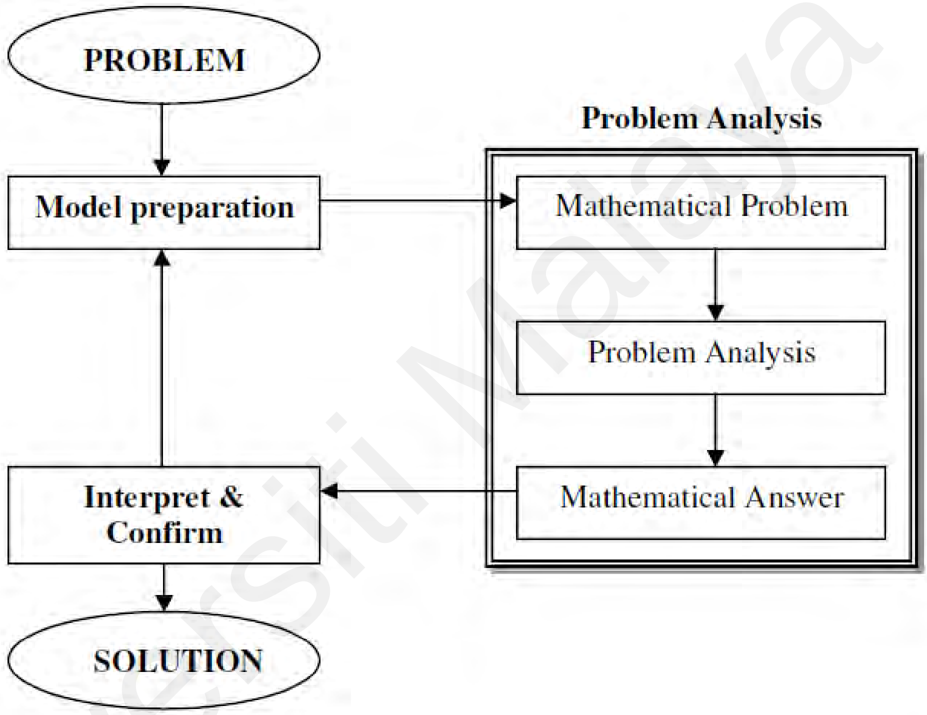


Figure 2.3 Savage & William's Problem Solving Model (Savage & William, 1990)

Another problem solving model produced for Physics Problem Solving is proposed by Heller and Heller (1995). They named the model Logical Problem Solving Model' which suggested five steps to solve Physics problems:

1. Give attention to the problem. In this step, the solver can make a sketch or write down the relevant information that maybe help them to solve the problem.

2. Describe Physics. Utilising the information written down in step 1, the relevant formula is chosen based on information's correlation with physics concept.
3. Make a plan to get the answer by involving the formula and information in step 2.
4. Execute the plan. The student executes the planned solution.
5. Evaluate the answer. The solver needs to check her work to see that it is reasonable and has answered the problem.

These recommendation steps of problem solving were made served a specific purpose, specific group or specific topic and may not be appropriate for describing other situations. Research also acknowledges the limitations of models and frameworks. Therefore, the task of developing problem solving models should not be regarded as complete just because a few models have been put forward (Yimer, 2004). Rather, there should be a continuous effort to modify and develop new models that include characteristics that previous models failed to capture.

In this study, problem solving involves a series of one-dimensional kinematics problems. One-dimensional kinematics is a topic in Physics that cover the concept about position, velocity and acceleration in one dimension. One-dimensional kinematics is usually introduced as the first topic to students in any Physics class. Due to the major ideas in this topic such as position, velocity, and acceleration, are incorporated into almost all other topics in physics (Manurung & Mihardi, 2016), it becomes necessary for students to master problem solving this topic, without a solid problem solving skill in this important topic, students lack the foundation necessary to succeed in Physics (Archambault, Burch, Crofton, McClure, 2008).

2.3 Metacognition

2.3.1 Definition and Its Conceptualisation

Metacognition has been known in the educational field since 1970 when John Flavell first mentioned it in his work. Although it has been known for decades, still, the term is difficult to define precisely (Zhang, 2014). It is often simply described as 'thinking about thinking' or 'knowing about knowing'. However, such a definition might be a bit vague and difficult for a non-expert to understand.

According to Flavell (1976) "Metacognition refers to one's knowledge concerning one's cognitive processes and products or anything related to them." (Flavell, 1976, p. 232). According to Flavell (1979), an individual will be considering engaging in metacognition if she notices that learning C is more difficult than learning D or if she notice he should check her answer before submitting it. Flavell's initial definition has been followed by many scholars and researchers who offered a different definition or added existing definition. Some of the quoted definition of metacognition are listed below:

Table 2.1

Comparison of Metacognition's Definition

Author (Year)	Definition
Flavell (1979)	Metacognition refers to one's knowledge concerning one's own cognitive processes or anything related to them
Brown (1978)	Metacognition is knowledge about one's own cognition that demands the ability to introspect about one's performance.
Baker and Brown (1980)	Metacognition is learner's knowledge and control that he has over his own thinking and learning activities.
Schraw (1994)	Metacognition refers to one's ability to reflect upon, understand, and control one's learning.
Fisher (1998)	Metacognition refers to that uniquely human capacity of people to be self-reflexive, to think about their own thinking and knowing.
Kuhn (2004)	Metacognition is defined in similar terms as awareness and management of one's own thought.
Veenman, van Hout-Wolters, & Afflerbach (2006)	Metacognition refers to the descriptive knowledge of, and the regulatory control over one's cognitive system
Rhodes (2019)	Metacognition refers to a set of processes an individual uses in monitoring ongoing cognition so as to effectively control his or her own behavior
Heyes, Bang, Shea, Frith, & Fleming (2020)	Metacognition is the ability to represent, monitor and control ongoing cognitive processes – helps us perform many tasks, both when acting alone and when working with others.

Metacognition has been described in the literature in many different ways, but perhaps the most cited definition is from Flavell's definition, metacognition is an individual's knowledge about his/her cognitive process, furthermore, it focuses on what s/he knows about how s/he learns, and how that individual regulates any aspect of cognitive processes. The origin of metacognition was explained by Kuhn (2000). He argued that metacognition emerges in the early life of an individual and grows more powerful and efficient under the individual's awareness (Kuhn, 2000, p 178).

Researchers have offered many different frameworks of metacognition. Generally, researchers distinguished metacognition into two components: knowledge and regulation (Flavell, 1987; Kluwe, 1982; Brown, 1987; Schraw, 2001) while a few of scholars offered a framework that includes self-regulation in metacognition components (Pintrich, Wolter & Baxter, 2000). Table 2.2 shows the comparison of the most quoted metacognition framework that is offered by scholars.

Table 2.2

Comparison of Metacognition Framework

Scholar(s) & Year	Knowledge	Regulation	Associated with Self-regulation
Flavel (1979)	Metacognitive Knowledge	Metacognitive Regulation	-
Kluwe (1982)	Knowledge of Cognition	Monitoring and Control	-
Brown (1987)	Knowledge of Cognition	Regulation of Cognition	-
Pintrich et al. (2000)	Metacognitive knowledge	Metacognitive judgment and monitoring	Self-regulation and control
Schraw (2001)	Knowledge of Cognition	Regulation of Cognition	-

There is no universal framework of metacognition (Carson, 2012). Thus, researchers who are going to conduct a study related to metacognition need to declare framework that they will use in their study (Smith, 2013). It will provide a consistent record of metacognition's concept and how it related to learning (Zohar & Barzilai, 2013).

This study assumed metacognitive knowledge and regulation as metacognition components. As for self-regulation, it is still a debatable idea among scholars and researchers whether self-regulation is one of the constructs of metacognition. Carson (2012) believed that self-regulation is widely considered to be part of metacognition while Efklides (2011) see metacognition as subordinate to self-regulation. Figure 2.1 shows the metacognitive framework that assumed in this study.

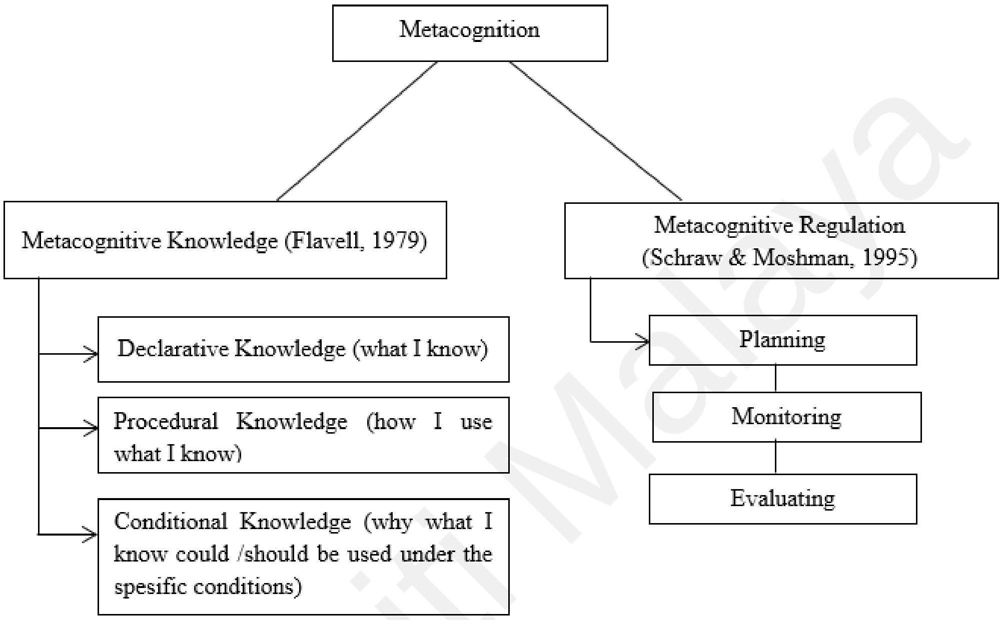


Figure 2.4 Metacognition Component

Metacognitive knowledge which also known as knowledge of cognition is an individual's awareness about his/her general cognition (Flavell, 1979). Many researchers (Flavell, 1979; Brown, 1987; Pintrich, et al., 2000 Schraw, 2001) distinguished metacognitive knowledge into three types of knowledge: declarative, procedural, and conditional.

- Declarative is an individual's knowledge about his/her strength and weakness as a learner (e.g., acknowledge that s/he has weakness in solving a problem related to logarithm).
- Procedural is an individual's knowledge about how to carry out his/her practical skills (e.g., knowing how to figure out an equation).

- Conditional is an individual's knowledge about when to employ a specific strategy and the reason behind it.

Metacognitive regulation is regulation of cognitive process (Flavell, 1979). It refers to the action that an individual can do to achieve the goal in learning. According to Flavell (1979), it includes planning, revising the plans and strategies, selecting a strategy, monitoring the plan, evaluate the result of all the activities.

Metacognition has been actively studied for years, and many data about metacognition were added to the existing theory. In the educational field, researchers believed that metacognition has a crucial role in education. It because of the reciprocal relationship between learning, cognition, and metacognition. Learning requires cognition and cognition are closely connected with metacognition. Learning is the process of gaining knowledge while cognition is the mental processes involved in gaining knowledge through thoughts, experiences, and senses include thinking, knowing, remembering, and problem solving. And metacognition is an individual's ability to reflect on his/her's cognitive process (learning) and make an adjustment to them. An example of how metacognition plays a role in learning will be shown by Alia's anecdote.

> "Tomorrow, Alia needs to present a short presentation about the rainfall cycle as an assignment from her teacher. To able to complete this assignment, Alia realizes she needs to understand the topic first, so she decides to read textbooks and makes note of an important point to include in her presentation. However, after reading it, she feels that her note is not explained enough about the rainfall cycle. She is panic as this is her only plan. However, Alia recalls that her teacher suggested a website when taught about the rainfall cycle. She

changes her strategy and searches the website that contains more information that she can use in her assignment".

This anecdote seems to describe what every student do if they have an assignment. However, if we dig beneath the surface of Alia's actions, the anecdote shows a simple example of how metacognition play its role in learning. Consider how Alia thinks hard about how to complete her assignment, pay some attention to the sources of her knowledge and make an adjustment to that, such as how Alia considers how she had to understand the topic before making her assignment and decide to read the resources first (textbook) then Alia realise it is not enough so she adjusts by using other resources (internet). In the anecdote Alia is proving to be a learner who regulates her own learning, having internalized a good strategy for planning, modifying and reflecting her learning. As Bransford, Brown, & Cocking (2000) stated that in term of learning or problem solving, metacognition is the processes when an individual made a plan, check, assess and if needed modify his/her learning behaviour.

Metacognition holds an important role because it enables students to keep tabs on their current ability levels, utilise learning resources efficiently, and assess their learning state (Schraw, Crippen, and Hartley, 2006). It helps the students control their work to achieve the desired goal as reflected by Alia's action in the anecdote.

2.3.2 Metacognition in Problem Solving

Problem solving is a goal-oriented process and metacognition is defined as knowledge of one own cognitive process guide and improves the efficiency in this goal-oriented process (Metcalfe & Shimamura, 1994). Teong (2000) believed that metacognition is a key factor to predict one's performance in problem solving.

Metacognition relates to students' awareness of their ability to develop various ways to solve the problem. According to Panaoura, Philippou, & Christou (2003) students who have the high metacognitive ability are better problem solvers because they able to analyse their strategies while solving the problem and evaluate on it then decide if they need to modify or choose another strategy to get the right answer. Schoenfeld (1992) argued that in problem solving, metacognition is used to monitor solution processes and to regulate the problem solving episodes of analyzing and exploring a task, making a solution plan, implementing the plan and verifying the answer. Using metacognition during problem solving is believed to allow an individual to monitor of their action and their plan and allow them to connect the information in the problem with their knowledge to get the solution (Davidson, Denser, & Sternberg, 1994) which increase the possibility of successful problem solving performance. Hence, no doubt educational researchers especially in science education acknowledge the importance of individual's metacognition in problem solving (Blummer, 2014) and suggest to foster metacognition in teaching problem solving.

There is a right reason why metacognition becomes interest topic for scholars and educators, especially who conducted studies in the field of problem solving. Metacognition was claimed to improve success in problem solving. Rickey and Stacey (2000) give an example of how metacognition has a great influence on the success of problem solving. They illustrate how important the presence of metacognition in problem solving by describing a failure case of problem solving as the disregarding metacognition aspect. A graduate student was asked to solve chemistry problems while doing verbalise their thought during the problem solving process. There are two problems that she needs to solve, a standard and simple problem and another one is an ill-structured problem that did not require broad knowledge to solve it. The graduate student started to solve the standard problem by reading the problem, making the inexplicit plan and instantly executing the plan. But during the process, she made one wrong assumption and did not realise it. Ironically, her assumption was wrong because the same principle that she would use to justify the formula for the second problem. She finishes the problem solving in a short time and did not bother to check her answer. At the end her answer was incorrect. Rickey & Stacy (2000) argued that this student has sufficient knowledge to solve the standard problem as she can solve the second problem which was more complicated than the previous one. The mistake she made is she overlooked a crucial relationship that she possibly would realise if she writes the equation she mentioned. Rickey & Stacy (2000) believed that her failure is led by poor monitoring and control during the problem solving process.

Kapa (2001) explained the six functions of metacognition during problem solving by comparing successful problem solver and unsuccessful problem solver, they are:

1) *Recognising and defining the problem.* Metacognition of an individual influence his/her ability to recognising the problem and define it correctly. When an individual is given a problem and read the problem statement, metacognition triggers their prior knowledge about the relevant concept of the problem. Kapa (2001) argued that unsuccessful problem solver tends to focus on non-relevant information from the problem.
2) *Representing the problem.* When solving the problem, an individual needs to know how to connect the information given in the problem with the relevant concept or theory of the problem. This process is related to metacognition. Kapa (2001) argued that an excellent problem solver spends more time to

analyse the information from the problem than an unsuccessful problem solver.

3) *Planning how to go forward.* Planning allows problem solver to decide what step they would take to reach the solution and in what arrange. If the problem is ill-structured, the problem solver's planning activity is found more explicit than if the problem is easy. Kapa (2001) mentioned three types of planning: step by step, trial-error, and holistic. She argued that expert problem solver formulates plan by generating a model for the situation of the problem and set up solution according to that model while novice problem solver made plan according to keywords or given information in the problem.
4) *Accomplishing the problem solving accordant with the plan.* This function related to monitoring and control which are metacognitive aspects. By monitoring and controlling, problem solver enables selecting, modifying, or terminating their plan during the problem solving process. Excellent problem solver tends to more aware of his/her action during the problem solving process rather than less successful problem solver.
5) *Assessing performance*. In problem solving process, a problem solver needs to aware of what s/he been done, what s/he need to do now, what s/he need to next, or if the strategy needs to be modified or terminated. When one works on a problem one needs to follow up what has been done, what one is doing at the moment and what remains to do or to fix. Reflecting on the action during the problem solving process is very crucial, it leads to a successful result. Successful problem solver was found to do the evaluating activity more than less successful problem solver (Kapa, 2001).

6) *Reacting to feedback.* Kapa (2001) argued that successful and less successful problem solver has a different reaction to feedback. A successful problem solver is responsive to feedback and utilises it to improve his/her performance, therefore they are recognised to have high self-monitoring. On the other hand, the less successful problem solver is indifferent to feedback, so s/he is likely to make the same mistake again.

Numerous scholars have conducted studies about metacognition and its role in problem solving. Some of the quoted argument of metacognition's role in problem solving are listed below

Table 2.3

Comparison of Metacognition's Role in Problem Solving

Role of Metacognition in Problem Solving	**Scholar (year)**
Metacognition allow students to monitor and regulate their problem solving activity	Lester, Garofalo & Kroll (1989)
Metacognition helps the problem solver: (1) recognise that there is a problem to be solved, (2) figure out what exactly the problem is, and (3) understand how to reach a solution.	Meltcafe (1994)
Metacognition helps students develop a better understanding	Lesh & Zawojewski (2007)
Metacognition improving problem solver's understanding and the use of appropriate strategies	Jacobse & Harskamp (2009)

Even though many researchers have given evidence how metacognition enhancing problem solving performance, it is still important to remember that utilising metacognitive activity does not always result in success in problem solving (Wilson & Clarke, 2002). This is because, in addition to the adequacy of an individual's knowledge base, problem solving may be affected by noncognitive factors, such as beliefs, schooling, and instruction (Garofalo, 1989; Goos & Galbraith, 1996; Schoenfeld, 1987).

Research that highlighted the role of metacognition in problem solving usually has two main directions (Smith & Mancy, 2018). First, understanding student use of metacognitive behaviour as Garofalo & Lester (1985) stated a reasonable way to begin to study the role metacognition plays in problem solving performance is to identify the metacognitive behaviour or action that can be employed during problem solving. Second, utilising metacognitive interventions, which more empirical evidence for the role of metacognition in enhancing problem solving and other areas comes from intervention studies (Smith & Mancy, 2018). However, this study examined the role of metacognition in problem solving by scrutinising student's metacognitive behaviour while solving the problem and how these behaviours help student completed the problem solving.

2.3.3 Metacognitive Behaviour and Its Framework in Problem Solving

As mentioned before, in problem solving process metacognition can be observed through behaviours that students exhibit. However, the behaviours that students exhibited during the problem solving process not only represent metacognition but also their cognition. Metacognition and cognition are closely related and often overlap each other. This phenomenon is well-known as the dual nature of metacognition. Cristoph (2006) stated that the dual nature of metacognition is one of the main issues in the concept of metacognition. The dual nature is referred to the intertwinement the metacognition and cognition. Metacognition and cognition are different matters but they are also related to each other. Scraw (2001) differed between metacognition and cognition in the sense that cognition is required to fulfil a chore on the other hand metacognition is necessary to understand how that chore will be performed. The anecdote below will describe one simple situation where metacognition and cognition are performed:

> *Mrs Rahma asks her students to do subtractions. She reads-out the numbers and demands her students to subtract the numbers. Her students will use their cognition to subtract the numbers. They will also utilise their metacognition, to think of how to subtract those numbers in the best way possible. Their thought might involve a strategy such as: "I'd better write down the operations in case I forget the number", or "I should check my result and do the subtraction once again so I don't make mistake". This kind of thinking what is called metacognition.*

To sum up the situation in the anecdote, cognition is knowledge about how to get a solution, such as how to subtract the numbers. While metacognition makes sure that the solution was reached efficiently and successfully, such as choose the best strategy while subtracting the numbers. However, sometimes it still difficult to distinguish the cognition and metacognition because metacognitive intention can conceal as a cognitive activity like check the answer of problem is identified as a cognitive activity but the intention to perform a checking activity is metacognitive behaviour.

According to Veenman, Van Hout-Wolters, & Afflerbach (2006) having an adequate metacognitive knowledge in one field requires substantial cognitive knowledge in that field such as understand about relevant concepts and theories, or about the troubles of that field. They give one example in a problem solving process, an individual can not do the planning without accomplishing the cognitive activity.

For example, a student can not check his answer without comparing the answer with the estimation or calculate again the answer using a different method.

Previous studies have discussed the dual nature issue and how to disentangle cognitive and metacognitive behaviour in problem solving. The results some of the studies offered a framework that can be used as a tool for analysing metacognitive behaviour during task performance such as problem solving. For research in metacognition in problem solving, a framework that highlight aspects of the person's behaviour in which metacognition are likely to be present is needed. Several researchers have offered a framework for analysing metacognitive behaviour in problem solving (e.g., Garofalo & Lester, 1985; Artzt & Armour-Thomas, 1992; Schoenfeld, 1992; Foong, 1993, Goos, 2002, Yimer & Ellerton, 2010).

Garofalo & Lester (1985) differentiated cognitive behaviour and metacognitive behaviour in a statement that cognition involves in doing on the other hand metacognition involves in making a plan, choosing a strategy, keeping tabs on what is being done. Garofalo & Lester (1985) offered a cognitive-metacognitive framework that composes of four activities generated in mathematical problem solving as showed in Figure 2.5. The framework illustrates the behaviours that represent metacognition characteristic and these behaviours linked with each activity in problem solving.

ORIENTATION: Strategic behavior to assess and understand a problem

A. Comprehension strategies
B. Analysis of information and conditions
C. Assessment of familiarity with task
D. Initial and subsequent representation
E. Assessment of level of difficulty and chances of success

ORGANIZATION: Planning of behavior and choice of actions

A. Identification of goals and subgoals
B. Global planning
C. Local planning (to implement global plans)

EXECUTION: Regulation of behavior to conform to plans

A. Performance of local actions
B. Monitoring of progress of local and global plans
C. Trade-off decisions (e.g., speed vs. accuracy, degree of elegance)

VERIFICATION: Evaluation of decisions made and of outcomes of executed plans

A. Evaluation of *orientation* and *organization*
   1. Adequacy of representation
   2. Adequacy of organizational decisions
   3. Consistency of local plans with global plans
   4. Consistency of global plans with goals
B. Evaluation of *execution*
   1. Adequacy of performance of actions
   2. Consistency of actions with plans
   3. Consistency of local results with plans and problem conditions
   4. Consistency of final results with problem conditions

Figure 2.5 Garofalo & Lester (1985) Cognitive-Metacognitive Framework

Artzt & Armour-Thomas (1992) offered a framework after investigating the behaviour of a small sample of students while they were solving mathematics problems.

Episode	*Predominant Cognitive Level*
Read	Cognitive
Understand	Metacognitive
Analyze	Metacognitive
Explore	Cognitive and metacognitive
Plan	Metacognitive
Implement	Cognitive and metacognitive
Verify	Cognitive and metacognitive
Watch and listen[a]	

[a]Level not assigned.

Figure 2.6 Artzt & Armour-Thomas (1992) Metacognitive Framework

According to Artzt & Armour-Thomas (1992) “cognition is involved in metacognitive activity, whereas metacognition possibly present but concealed during a cognitive activity” (p. 141). In their framework, Artzt and Armour-Thomas (1992) reading is the only activity that tagged as cognitive, while understanding, analysing and planning are tagged as a metacognitive activity. On the other hand, exploring, implementing and verifying are tagged as both depend on if the activity related to information processing or if it related the statements about the problem.

Schoenfeld (1992) observed students problem solving behaviour and noted the distinct behaviours that he called ‘episodes’ and he categorised these behaviours as metacognitive behaviour, they are analysing the problem situation, recalling related knowledge, formulated a plan, carrying the plan, and assessing the answer.

Foong (1993) conducted a study to develop a framework for analysing think aloud data in the problem solving process. Foong offered a framework that divided individual behaviours during problem solving into cognitive behaviour, metacognitive behaviour, and affective behaviour. The metacognitive behaviour classified by Foong (1993) showed in the figure below.

M-Category: Metacognitive Behaviour

M1 - Suggest a plan
M2 - Assess task facility
M3 - Review progress
M4 - Recognise error
M5 - Recognise new development
Q1 - Task-relevant self-question
N1 - Task-irrelevant rhetoric

Figure 2.7 Foong (1993) Taxonomy of Metacognitive Behaviour

Goos (2002) offered a framework that consists of detail types of metacognitive behaviour that she expect would be present in each stage of problem solving as shown in Figure 2.8.

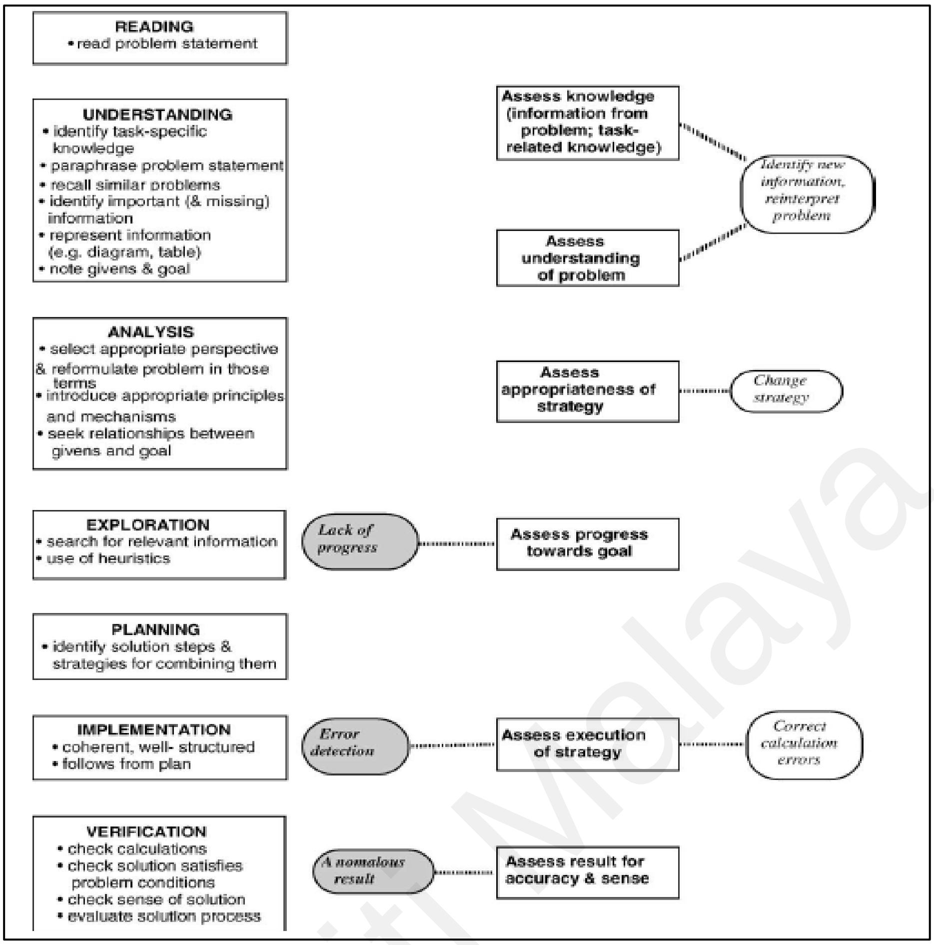


Figure 2.8 Goos (2002) Metacognitive activity model

While previous frameworks tagged the problem solving stage as cognitive or metacognitive behaviour, Goos's framework considers the types of activities such as monitoring and regulating in detail. For example, in understanding stage, evaluating the sufficiency of one' knowledge about the task is categorised as monitoring activities.

The last frameworks will be discussed is Yimer & Ellerton (2009). Yimer & Ellerton (2009) conducted a study that aims to identify and characterise the metacognitive behaviours of preservice teachers while they engage with mathematical problem solving. The result of their research was the five-phase metacognitive framework, which is presented in Figure 2.7.

COGNITIVE AND METACOGNITIVE CATEGORIES

1. **Engagement**: Initial confrontation and making sense of the problem.
   A. Initial understanding (jotting down the main ideas, making a drawing)
   B. Analysis of information (making sense of the information, identifying key ideas relevant information for solving the problem, relating it to a certain mathematical domain)
   C. Reflecting on the problem (assessing familiarity or recalling similar problems solved before, assessing degree of difficulty, assessing the necessary store of knowledge one has in relation to the problem)
2. **Transformation-Formulation**: Transformation of initial engagements to exploratory and formal plans.
   A. Exploring (using specific cases or numbers to visualize the situation in the problem)
   B. Conjecturing (based on specific observations and previous experiences)
   C. Reflecting on conjectures or explorations whether they are feasible or not.
   D. Formulating a plan (devising a strategy either to test conjectures or devising global or local plans)
   E. Reflecting on the feasibility of the plan vis-à-vis the key features of the problem
3. **Implementation**: A monitored acting on plans and explorations.
   A. Exploring key features of plan (breaking down plan into manageable sub plans where necessary)
   B. Assessing the plan with the conditions and requirements set by the problem
   C. Performing the plan (taking action by either computing or analysing)
   D. Reflecting on the appropriateness of actions
4. **Evaluation**: Passing judgments on the appropriateness of plans, actions, and solutions to the problem
   A. Rereading the problem whether the result has answered the question in the problem or not
   B. Assessing the plan for consistency with the key features as well as for possible errors in computation or analysis
   C. Assessing for reasonableness of results
   D. Making a decision to accept or reject a solution
5. **Internalization**: Reflecting on the degree of intimacy and other qualities of the solution process.
   A. Reflecting on the entire solution process
   B. Identifying critical features in the process
   C. Evaluating the solution process for adaptability in other situations, different ways of solving it, and elegance
   D. Reflecting on the mathematical rigor involved, one's confidence in handling the process, and degree of satisfaction

Figure 2.9 Yimer & Ellerton (2010) Metacognitive Framework

All of the researchers who offered the metacognitive behaviour framework acknowledged the difficulty of identifying one's metacognitive behaviour during problem solving as that some of the one's thoughts may not be verbalised. Behaviours labelled as metacognitive in every study are those that are audible to the observers (Artzt & Armour-Thomas, 1992). Hence, the identified metacognitive behaviours in this study are those that audible to the researcher. In this study, Yimer & Ellerton's framework was used as guidance to identify metacognitive behaviour in the problem solving process of one-dimensional kinematics. It is because Yimer & Ellerton (2010) framework presented the metacognitive behaviour that expected to present during problem solving in detail and categorised them in descriptive phase. This framework encompasses the previous frameworks therefore it was was used to identify metacognitive behaviour during problem solving in this study.

2.3.4 Assessing Metacognition in Problem Solving

Assessing metacognition is not easy because metacognition is not explicit behaviour (Akturk & Sahin, 2011) and metacognition is domain-specific which means that metacognitive behaviour may differ from one task to the other (Jacobse & Harskamp, 2012), example reading comprehension versus problem solving. Metacognitive behaviour for reading comprehension encompasses reading the headings, skimming the writing to summarise, and recalling the knowledge. While in problem solving, metacognitive behaviour involves rereading the problem situation, recalling the knowledge, and arranging information given and the goal asked for (Veenman, Van Hout-Wolters, Afflerbach, 2006). Thus, the measured metacognition needs to be specific and clear (McNamara, 2011).

Veenman et al. (2006) stated that metacognitive processes in problem solving can be assessed *offline* or *online*. Online measures assess any metacognitive behaviour while an individual is engaging in the task, whereas offline measures any behaviours that happen before or after task performance (Treglia, 2018). According to Veenman (2011) for offline measures, self-report questionnaires and interviews are the most frequently used, while observation and think-aloud techniques are used for online measures. A questionnaire is asked the subjects to report their own metacognition (e.g. Metacognitive Activities Inventory) (Cooper & Sandi-Urena, 2008)). The questionnaire typically contains general statements about metacognitive behaviour such as "I reread the problem statement to fully understand the goal of the problem" or "I check my calculation before proceed to the next step" (Cooper &

Sandi-Urena, 2008). However, there are some issues about using self-report to assess metacognition. First, memory distortion issues (Veenman, 2011) because the questionnaire is collected before or after task performance, students are required to retrieve the earlier process from their long term memory. Second, misunderstanding issues, there is a possibility that a statement in the questionnaire differ with what students refer as to which activities they have in mind when interpreting the statement (Sandi-Urena, 2008). Third, bias issues (Veenman, 2011), because students were asked to label their own behaviour, this issues is unavoidable.

Interviews are another popular method to assess metacognitive behaviour (Baker & Cerro, 2000). Interviews can be conducted in different formats, for example, open-ended and closed; structured, semi-structured, and unstructured; introspective and retrospective. An interview is a powerful method as it enables an in-depth examination. However, if the study involves many participants, requires a lot of time since the interview involves conveying information by asking and responding question (Scott, 2008).

Jacobse and Harskamp (2012) argued that the benefit of online measures is it allows the concurrent assessment during task performance, so it gives more information into the actual use of metacognition that affects the performance. Think aloud protocol and observation are two methods online measures that frequently used to assessing metacognition in problem solving (Sandí-Ureña, 2008).

Think aloud is a technique where the author asked the subject to verbalise their thought as they solved a problem such as a mathematics question, puzzle, or reading a problem (Charters, 2003). Ericsson & Simon (1980) argued that the objective of using think-aloud is to verbalise the individual’s thought while doing a task. Wallace (2014) stated think-aloud is a technique well suited to examining cognitive processes and is now an established technique used in investigating student's strategies and behaviour while solving the problem.

Think aloud are usually used simultaneously with observation. As observations allow the observant to determine the subject's non-verbal behaviour. However, to set up the think-aloud to assess metacognitive behaviour, there are some points the researcher should consider (Katalin, 2000):

- Instruction

  The instruction of think aloud should be focusing on the research goal (Katalin, 2000). It should allow the subject to voice everything that comes to their mind, it should not limit the subject to specifically say the answer that they think the researcher what to hear from them.

- Selecting the Task

  A task for think aloud needs to be chosen carefully by considering the subject cognitive ability (Charters, 2003). The problems selected for the think aloud should not be so difficult that the participants cannot give a complete problem solving, the problems also should not be too easy that the participants have an automatic solution to the problems (Phang, 2006). Ericsson and Simon (1980) believe that difficult task creates a "cognitive load" and will affect the verbalisation and an easy task is also inapplicable because the subject maybe has the automatic solution for the task (Pressley & Afflerbach, 1995).

- Think-aloud Training

  Think aloud is not a common task for most of the participants. Some of the participants may found is not easy to think and speak at the same time (think aloud), hence a training of think aloud is needed. As Ericsson & Simon

(1980) found that training the participants before record their think aloud session is important.

- Eliciting Verbalisation

  Katalin (2000) found that during the think aloud session, sometimes the participant would keep quiet or forget to do think aloud, so the researcher needs to do something to elicit verbalisation without too much interference.

- Other Source of Information

  According to Charters (2003), many works of literature about think aloud suggest that research can not only rely on think aloud transcripts as the source of data. Ericsson and Simon (1980) believed that data from think aloud is always incomplete because it excludes a few thought processes that are not held long enough in participant working memory. Therefore, the researcher needs to use a follow-up strategy to support the think aloud data (Katalin, 2000).

In this study, think-aloud and observation were used as online measures and retrospective interview as offline measures also used to support data from think-aloud and observation.

2.4 Related Research in Metacognition in Problem Solving

For almost four decades, the different area of metacognition has been becoming the focus of numerous research. The following part will elaborate on a few studies that closely related to this study. However, it is important to point out one thing at the beginning, several studies described in this section are not in Physics domain or one-dimensional kinematics. Nonetheless, these studies do gives useful information that applies to one-dimensional kinematics problem solving, because problem solving is a concern in many fields and it shares the same characteristics.

Phang (2006; 2009) conducted two related studies about the pattern of metacognition in Physics problem solving. First, she conducted case study research to examine metacognitive skills in Physics problem solving. Her first study involves six students in Cambridge. Think aloud was used as a data collection method followed by a semi-structured retrospective interview. Six problems of linear motion were used as instruments. She identified five categories of metacognitive skills, they are memory, planning, interpreting, checking, and reflecting. Phang's second study involved larger participants and the broader topic of physics. Phang (2009) conducted grounded theory research that aims to identify metacognitive skill in Physics problem solving and examine the role of metacognition in Physics problem solving. Think aloud, retrospective interview, and observation were used to collect the data from 26 students. The result showed that five categories of metacognitive skill emerge from student's problem solving: monitoring, regulating, reflecting, evaluating, and justifying. The result also showed that metacognition allows students to monitor, regulating, reflecting, evaluating and justifying their progress during the problem solving process.

Karnain (2014) conducted a qualitative study that aims to examine students' use of metacognitive skills in problem solving process. The study involved students from twenty-one secondary school in a rural Anambas, Indonesia. The study designing to explored the metacognitive skill of students while solving individually mathematical problems. The thinking aloud protocol was conducted during the problem solving activities. Result of analysis of students written work and thinking aloud showed how students utilised their metacognitive skills in problem solving process. The result also showed that metacognitive skills exhibited by students have different levels. The identified metacognitive skills involve planning, monitoring, and evaluation activities. Students are found utilising the used planning and monitoring skills at a different level. Besides, the result also showed that students who combining metacognitive skills during problem solving manifested a higher level of monitoring activities.

Barbasena & Sy (2015) conducted a study to describes metacognitive action and metacognitive functions of the learners in mathematics problem solving. Eighteen junior students who major in Mathematics Secondary Education of Bicol University College of Education were the subjects of the study. Each student answered the problem and then write their reflections as to what went on their minds as they were answering the questions. The study finds that the students were found to employ the following metacognitive skills as they solve the problems: recalling, representing, identifying relations, elaborating, defining the problem, establishing criteria, setting goals, comparing and verifying. Barbasena & Sy also classified metacognitive functions into three categories: metacognitive awareness, metacognitive evaluation and metacognitive regulation. They conclude that students who took advantage of metacognitive functions resulted to present a better quality of an answer.

Sagirli (2016) conducted a case study to examine cognitive-metacognitive behaviours that pre-service mathematics teachers' of secondary school exhibit while solving a mathematics problem based on the grade they taught. Eight pre-service teachers from one university Erzincan, Turkey participated in the study. The verbal protocol was used to collect the data and a modelling mathematics question was used as an instrument. The study involved two stages, which the first stage the data was collected from convenience sampling and the second stage, the data was collected from typical situation sampling. The result showed that the participants in their study believed that metacognition supports their problem solving by allowing them to understand and detailing the problem, allow them to carry out their plan, selecting an alternative strategy to get the solution. Sagirli (2016) claimed that when the metacognitive support was provided, the participants showed more successful performance compared with the first stage when no metacognitive support was provided.

Abdullah (2017) conducted a study to investigate the metacognitive behaviour of Malaysian students while solving mathematic problems of form three assessment. He also intended to differentiate metacognitive behaviour among successful students. Successful students referred to as 'SS', partially successful students referred to as 'PSS', and unsuccessful students referred to as 'USS'. He collected the data from six Form Three students in one school in Johor Bahru using think aloud protocol. The identification of metacognitive behaviour was based on Foong Taxonomy (1993). He found seven metacognitive behaviours that students exhibit while solving the problem, they are: proposing the plan, identifying the difficulty of the problem, review the development, identifying mistake, identifying new knowledge and asking a relevant question. The result also showed each category of students (SS, PSS, USS) exhibit different types of metacognitive behaviour while solving the problems. The SS category is found able to control their metacognitive behaviour during the problem solving process more often and regularly than the other category of students. the PSS students exhibit metacognitive behaviours moderately, while the metacognitive behaviour that USS group exhibit is limited.

2.5 Theoretical Framework

In educational research, there is always a theory underpinning every study conducted. Theories are constructed to explain, predict and master a situation or phenomena. A study needs to formulate a theoretical framework that outlines the whole study. The theoretical underpinning of this study derives from Schoenfeld's theory of mathematical behaviour (1985). Although Schoenfeld conducted studies on mathematical problem solving, many researchers accept Schoenfeld's theory for general problem solving which involve algebra such as Physics problem solving (Kuzle, 2015).

Schoenfeld (1985) claimed that individual's behaviour in solving problems is determined by four aspects: (1) the individual's *knowledge*; (2) the individual's ability to use *heuristic*; (3) the individual's skill at *controlling* his/her use of knowledge and heuristic; and (4) the individual's *beliefs* about the topic and himself. 'Knowledge' refers to an individual's knowledge of the problem s/he engaged which includes theory, concepts, definitions, and algorithms. If a student trying to solve kinematics problem, naturally she needs to know about velocity, distance, and formula in kinematics. 'Heuristic' is an individual's problem solving strategies that one employs in an attempt to formulate pathways to a solution. 'Control' involves an individual's decisions management regarding the selection and implementation of knowledge and heuristic. Last, 'belief' refers to the individual's attitudes about oneself, task and its topic, environment. Schoenfeld believed that insufficiency in any one of these factors can ruin a solver's attempt to solve the problem successfully.

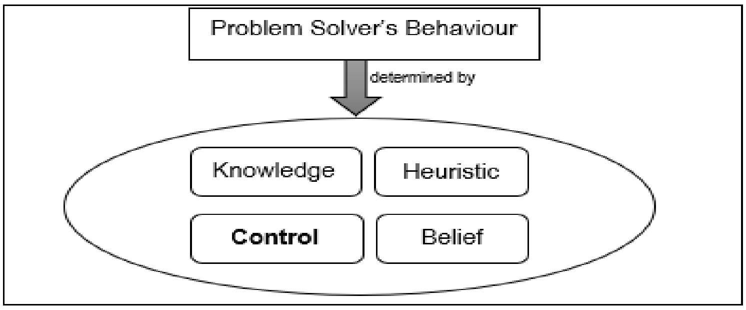


Figure 2.10 Schoenfeld's Theory of Mathematical Problem Solving Behaviour

This study related to the third factor mentioned in Schoenfeld's theory: control. *Control* deals with decisions-making during problem solving, a decision about what to do, decisions how to use their knowledge efficiently to solve the problem, the decision if the individuals will make or terminate an attempt to solve the problem. In the literature, this phenomena called *metacognition*. According to Schoenfeld (1985) deficiencies in metacognitive aspects are a fundamental cause of students' failures when solving problems. Schoenfeld gives one example of a student who has excellent knowledge and a good strategies control but still fails to solve the problem because they do not assess their progress at the essential period during the problem solving process. Schoenfeld (1985) also noted that students who lack metacognitive skill, often perform meaningless calculations without giving much thought to the problem, solve problems without any planning and evaluating of their problem solving approach, and give up easily if the problem is not solved in time as a result of emotions such as frustration.

In his later studies (Schoenfeld, 1987; 1992), Schoenfeld paid more attention to the influence of metacognition in problem solving. Schoenfeld (1992) observed that students show distinct behaviours while solving the problem. Schoenfeld (1992) categorised these behaviours and named the categories as 'episodes'. Schoenfeld noted the important episodes are analysing the problem situation, recalling related knowledge, formulated a plan, carrying the plan, and assessing the answer. He also found that experts who successfully solve an unfamiliar mathematics problem exhibit in metacognitive behaviours more than the beginners. Therefore, Schoenfeld (1992) and other influential researchers in the area of metacognition in problem solving, regard metacognitive behaviours as the 'driving forces' in problem solving, influencing cognitive behaviour at all phases of problem solving and affecting the performance in problem solving.

This study only focuses on metacognition area, because the issue addressed in this study is poor problem solving performance due to lack of metacognitive skill. However, it does not mean metacognition is more important than other factors. This study assumes that metacognition has a crucial role in the problem solving process. Figure 2. Illustrates the theoretical framework used in this study.

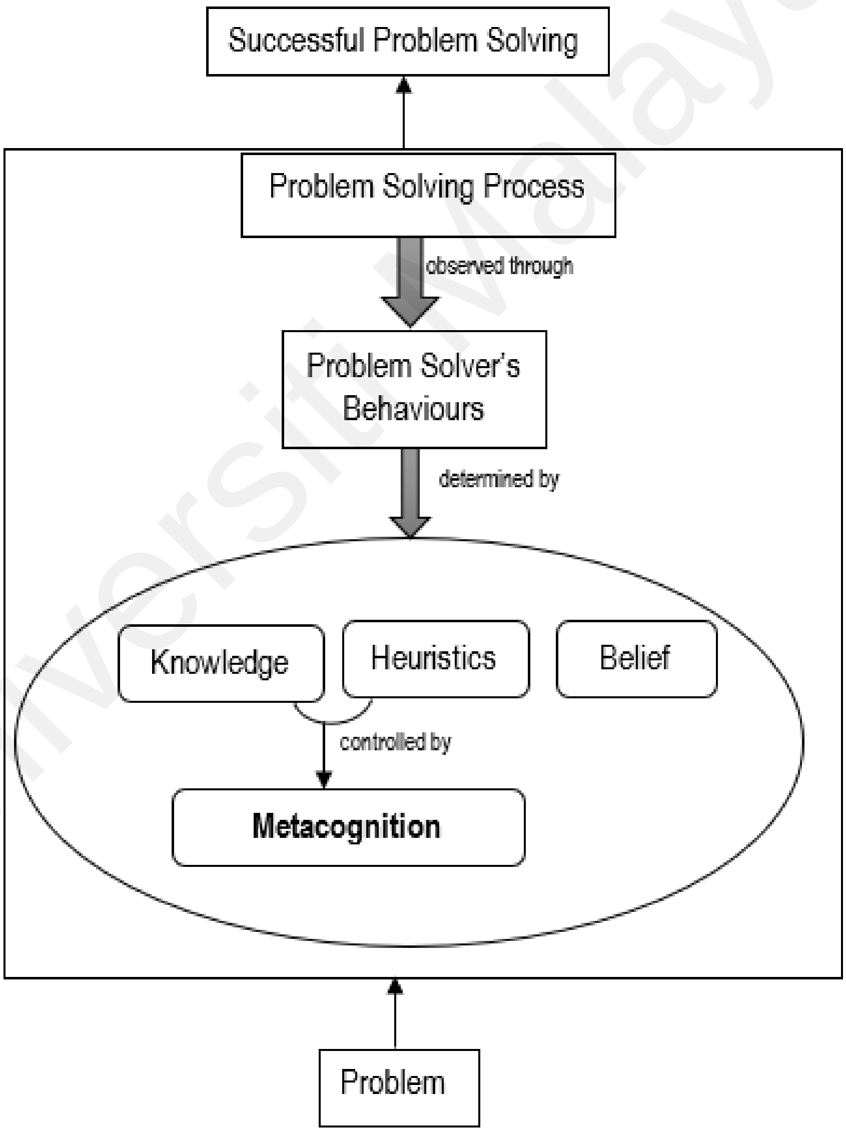


Figure 2.11 Theoretical Framework

According to the theoretical framework, obtaining successful problem will be influenced by the internalised scheme during the problem solving process. During the problem solving process, all of the problem solver's behaviours will be determined by four-factors, problem solver's knowledge, problem solver heuristic, problem solver's metacognitive skill, and problem solver's belief. Although all of four-factor was equally important in problem solving, this research intends to investigate metacognitive aspects contributes in problem solving process in one-dimensional kinematics topic, thus Schoenfeld's theory of mathematical behaviour (1985) will support this study.

2.6 Conceptual Framework

The conceptual framework of the study is the main component of this current study as it shows the reader how this study flows to reach the objective. The study focuses on metacognition in the problem solving process for one-dimensional kinematics. The objectives of this study are to identify metacognitive behaviour that students exhibit while solving one-dimensional kinematics problem and to examine the role of metacognition in the problem solving process of one-dimensional kinematics. Figure 2.11 shows the conceptual framework of this study.

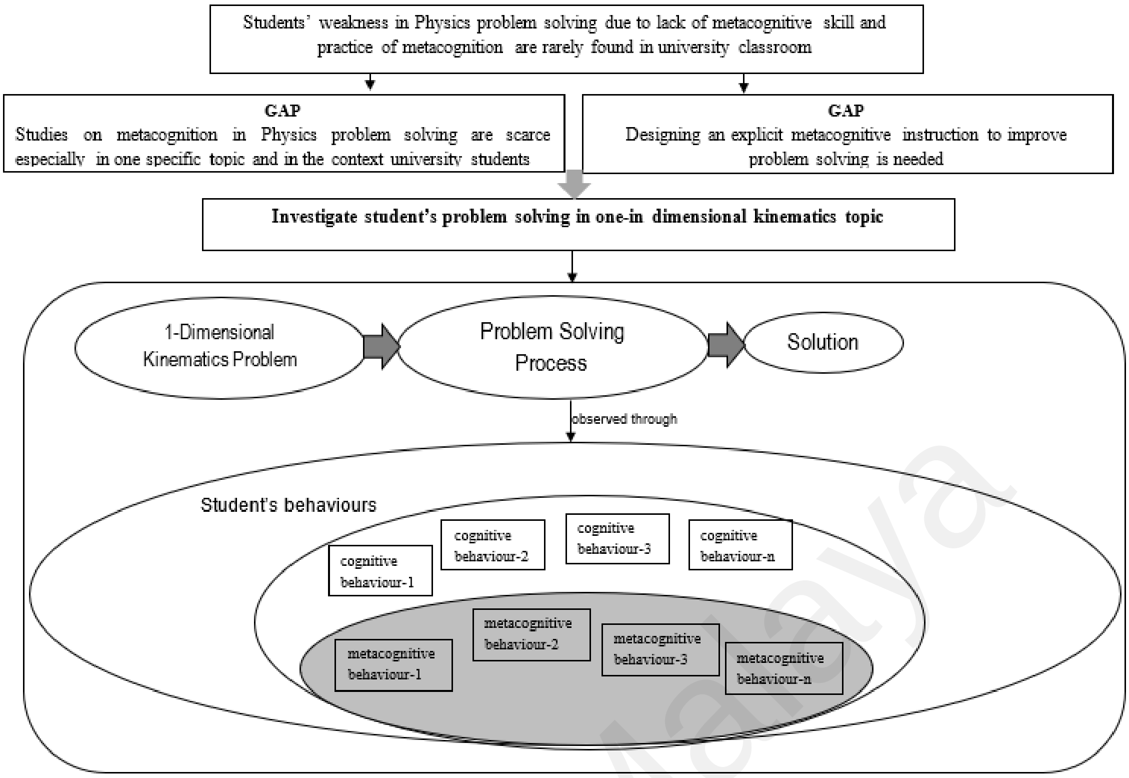


Figure 2.12 Conceptual Framework

According to the conceptual framework chart, problem rose when students' problem solving performance is poor due to a lack of metacognitive skill and practice of metacognition are scarce in the university classroom. Researches suggest there is a need to design a metacognitive explicit instruction to teach how to use metacognition in problem solving and increasing a successful performance of problem solving. Designing metacognitive explicit instruction requires preconception data about metacognition in problem solving. However, resources about metacognition in the problem solving process for a particular topic such as one-dimensional Kinematics and in the context of university students are limited. The gaps were found, hence to reduce gap this study intended to provide preconception data for the development of explicit instruction by identifying metacognitive behaviour that student exhibits while solving one-dimensional kinematics problems and examining the role of metacognition in problem solving process of one-dimensional kinematics.

To fulfil the objectives of the study, the study has been designed to investigate students' problem solving process in one-dimensional kinematics topic through their behaviour while solving one-dimensional kinematics problems. When a student is given a problem task and he/she try to solve the problem, the behaviours of the student involve his/her cognition and metacognition. His/her attempt to solve the problem is a cognitive process and metacognition supports this process. Metacognition support student's cognitive process which is an attempt to solve the problem. For example, metacognition will emerge as the student tries to understand the problem situation and how to get the solution. Hence, as the student attempts to solve the task, metacognitive behaviours will take place through the process along with cognitive behaviours. Metacognitive behaviours influence a student's in decision-making while solving the problem and affect student's performance in problem solving. Because the interactions between the problem and the internalised problem solving schemes are critical to the solution of a problem.

2.7 Summary

This chapter provides elaboration about problem solving, definition and conceptualisation of metacognition, metacognitive behaviour, how to assess metacognition in problem solving, previous studies related to this study. Moreover, this chapter includes a theoretical framework to explain the theory and concept used to justify this research. Also, this chapter provides the whole idea of research that depicted into a conceptual framework. The research methodology for this study explained in the next chapter.

CHAPTER 3

METHODOLOGY

3.1 Introduction of the Chapter

This chapter is outlining the research methodology that generates a suitable research design to answer the research questions including the chosen research method, description of data collection techniques and tools, selection of participant, research procedures, and data analysis. This section also discusses the trustworthiness of the study and ethical consideration.

3.2 Research Method

This study aimed to develop a better understanding of metacognition in problem solving process of one-dimensional kinematics by observing students' metacognitive behaviour while they engage in problem solving process and examine the role of metacognition in problem solving process of one-dimensional kinematics. Given this information and other deliberations (assumptions, tools, sample and approach of this study), the researcher believed that the qualitative method is more suitable to fulfil the aim of this study. Silverman (2017) suggested qualitative methods are usually the most appropriate if you want to understand social interaction in real-life situations, understand how people perceive things, understanding the process such as decision making or teaching a class.

3.3 Data Collection Technique

Data collection techniques hold an important role in any type of research. Any inaccurate data collection techniques may lead to an invalid result and affect the result of the study. According to Merriam (1998), data collection used in the study is determined by the researcher's theoretical orientation, problem, the objective of the study, and the sample selected. In this study, think-aloud, retrospective interview, observation and analysis of answer sheet were used as the data collection technique. Think aloud as the core method was supported by the retrospective interview, observation, and analysis of the answer sheet to ensure that the data is 'grounded' and to strengthen the trustworthiness of the research.

3.3.1 Think Aloud

Think aloud is a technique where the author asked the subject to voiced their thought as they solved a variety of problems such as a mathematics question, puzzle, or reading problem (Charters, 2003). Ericsson & Simon (1980) argued that the objective of using think-aloud is to verbalise the individual's thought while doing a task. Wallace (2014) stated think-aloud is a technique well suited to examining cognitive processes and is now an established technique used in investigating student's strategies and behaviour while solving the problem. In this study, instructed the participant to do think aloud means instructed them to voice their thought while solving one-dimensional kinematics problems.

Think-aloud is chosen as a data collection technique in this study because it is well suited with the objective of this study which is to investigating problem solving steps and metacognitive behaviour while students solve the problem. As Wallace (2014) who used think-aloud techniques in his dissertation argued that think-aloud requires the student to talk through the problem out loud whilst solving it, providing information on the processes used by the student to get to a solution that a written answer may not.

The think aloud technique has been used in previous researches related with problem solving and metacognition (Phang, 2009; Kuzle, 2011; Wallace, 2014;

Zhang, 2014) as some researchers found that the method is useful to provide information during problem solving process (Phang, 2006).

Using think aloud as the data collection technique, the researcher's need to make measured preparation and arrangement (Katalin, 2000). Therefore, in this study the preparation of think aloud consider some important points, they are:

- Instruction

  The instruction of think-aloud that participants received is important. Katalin (2000) argued that instructions for think-aloud should be focused on the research objectives. Therefore, the participant in this study was given problem tasks on a piece of paper. The instruction given is to solve the problem and verbalize anything that comes to his/her mind, it could be intuitive feeling, doubts, ideas or any thoughts while solving the problems (Phang, 2006). The researcher observed the participant as she solved the problem by thinking aloud while the verbal responses were recorded. To avoid any intervention during the think-aloud process, during problem solving the participants were given only the problem task, paper, pen, and calculator. They are prohibited from using other resources such as textbook and the internet. However, students were informed that they could use calculators if they felt they were needed. The students also were not given time-limitation while solving the problem to ensure they engage in problem solving without feeling rush.

- Think aloud Training

  Think aloud is not a common task for most of the participants. Some of the participants may found is not easy to think and speak at the same time (think aloud), hence a training of think aloud is needed. However, Katalin

(2000) found that after short training of think aloud, students aged over 16 years old were capable to verbalise and articulate their thought. In this study, as all of the participants are over 16 years old, only a short training session was conducted before the think-aloud process. The short training session started with the researcher explained what is think aloud and how to do it with a quick demonstration to the participant. The researcher also provided a short think-aloud video to show participant what they are expected to do. Before the think aloud session started, the researcher also gave the participant a chance to practice with the warm-up problem. When the participant is ready, the think-aloud will be started.

- Eliciting Verbalisation

  Katalin (2000) found that during the think aloud session, sometimes the participant would keep quiet or forget to do think aloud, so the researcher needs to do something to elicit verbalisation without too much interference. Previous researchers have offered a few suggestions about how to elicit verbalisation such as giving a signal to the participant to remind them to talk. Therefore, during this think-aloud session in this study, the researcher and the participants agree to use the sentence "please keep talking" as a signal to elicit the verbalisation.

- Other Source of Information

  According to Charters (2003), many studies about think aloud suggest that research can not only rely on think aloud transcripts as the source of data. Ericsson and Simon (1980) believed that data from think aloud is always incomplete because it excludes a few thought processes that are not held long enough in participants working memory. In response to these problems, this study used retrospective interview transcripts, observation field notes and students' answer sheet as another source of data. These follow-up techniques may also be used as a validation of the researchers' interpretation from participant's think-aloud utterances.

- Selecting the Task and Participants

Selecting the task and participants for the think-aloud technique also needs careful consideration. The problems selected for a think aloud should not be so difficult that the participants cannot give a complete problem solving, the problems also should not be too easy that the participants have an automatic solution to the problems (Phang, 2006) (Problem task in this study will be explained in the section below 3.4.1 Problem Task).

Although the problem task is prepared carefully, every individual has different cognitive abilities, then students will have a different view on the difficulty level of the problem. Thus, it is important to select the participant who views the problem task given by the researcher as 'real problem'. (More criteria for participants in this study will be explained in 3.5 Selection of Participants)

3.3.2 Observation

Creswell (2014) said that observation in a qualitative study, the researcher needs to take notes on the individuals' behaviours and actions at the research site. In this study, a non-participant observation was conducted where the researcher observed the behaviour of participants and his/her interaction with the task continue without the presence or interruption from a researcher. The main purpose of observation in this study is to prepare questions for the interview aimed to get information and clarifying students' behaviour during problem solving. Questions and short field notes were written down during observation. In this study, during the observation, the researcher observed the behaviour of participants and her interaction with the problem without the interruption from a researcher and the researcher also took the notes to highlight some of the students' behaviour or action during think-aloud that need clarification such as when students said the words 'this' and 'that' (which cannot be determined through protocols). The observation was done throughout the process of students solving the problems while doing think aloud.

An observation protocol was used during the observation. The protocol was adapted from Creswell (2014). As suggested by Creswell (2014) while conducting an observation researcher should use and prepare an observation protocol for storing information while observing. The observation protocol in this study was a page consist of a table with two-column and a diving line down to the middle to split descriptive notes (See Appendix B). The notes in this study were taken to help provide information about students' non-verbal behaviour and to prepare questions for the retrospective interview to clarify students' particular behaviour during think-aloud.

3.3.3 Retrospective Interview

According to Merriam (1998), the most common data collection technique used in qualitative research in education is probably interview (Merriam, 1998). The interview used in this study was semi-structured interviews which comprise a few central questions that help to guide the interview, but also allows the researcher or participants to pursue an answer in more detail (Gill, Stewart, Treasure & Chadwick, 2008). This type of interview is chosen because of the flexibility of it. This method allows the researcher to discover the important information that may not have previously been thought by the researchers.

In this study, the interview called retrospective because it involves questioning the participants after they solve the problem while doing think aloud (Wallace, 2014). The asked questions aim to clarify their action during the problem solving process or provide more data in detail. This means questions such as *how you find the solution to that problem?* or *Why did you use do ....(the strategy or method) to solve the problem?* will be asked after students solved the problem. This interview is important in this study, as Ericsson and Simon (1980) stressed, data from think aloud is always incomplete because it excludes a few thought processes that are not held long enough in participants working memory. According to Charters (2003), a retrospective interview is a method that most widely used as a followup strategy to complete think aloud. The retrospecti interview needs to be completed soon after the participants finish solve the problem to ensure that participants do not forget the justification for their action (Rowe, 1991). Their solution will be placed in front of them, and the participants will be asked what they were thinking at each point of the interviewer's choice.

The retrospective interview protocol was used in this study. The protocol consists of a set of questions specified by Charles, Lester & O'Daffer (1992) as a guide (See Appendix A). These questions also used by several researchers who conducted a study in problem solving and metacognition such as Phang (2006, 2009) and Rosli (2013). These questions were translated and consulted to the expert to get approval and feedback. A few translation adjustments were made in the retrospective interview protocol based on feedback from the expert (Appendix G) such as fixed the wrong word and changed the vague sentence into a suitable sentence. These questions were also piloted to one student to ensure the students understand the interview question and prevent misunderstanding in interpreting the meaning of the questions after the translation. (See 3.5 Pilot Study). During the interview, some questions also raised from observations that were asked to clarify students' actions and to ensure that the interpretations based on the researcher's observations were confirmed by the students.

3.3.4 Document Analysis

Document analysing is one of the data collection technique suggested in a qualitative study. In this study, the used document was the participants' actual answer sheets. The researcher examined answer sheets and compared it to the think aloud recording, thus the researcher able to view students' problem solving process visually. Answer sheet supported the interpretations of the think aloud recording. It also shows the paths that the student took and the key information that the student has written down, especially when the problem is transformed into students' representation.

3.4 Problem Task

For this study, eight problems from one-dimensional kinematics topic were chosen according to the characteristics of the problem suggested by Ray (1995). According to Ray (1955), the problems used in research related to problem solving should be:

a. the solution description about successful or unsuccessful is clear
b. the problem allows students to do two or more procedures to reach a solution, in other words, allows students to predict and discover another procedure if they fail at one procedure

These eight problems were chosen from various resources such as research before (Phang, 2009) and Physics textbooks for university students (Bueche, 2006; Halliday & Resnick, 2005; Young & Freedman, 2002). As for the problems from the journal, the researcher has already got permission from the author to use the problems for this study. As a few problem tasks are not available in the language required for the targeted participants (Bahasa Indonesia), the problems were translated into Bahasa Indonesia. The translation done is back-translation with help of translator from Syiah Kuala University Language Center. After the translation, the problem tasks were consulted to the Bahasa Indonesia expert to get approval and feedback (See Appendix G).

After the problems were chosen and the translation was formalised, a small pilot testing was conducted. The aim of this pilot testing was not to pilot test the problems per se but to ensure that the researcher has the appropriate tool for selection test and think aloud session since the researcher is not familiar with the ability of problem solving among the first-year Physics Education students. This pilot test of the problem task also to ensure that students understand the problem and to prevent misunderstanding in interpreting the meaning of the problems after the translation.

Pilot testing was conducted on the eight problems and involves nine first-year students from Physics Education Department. The students were instructed to solve eight problems focusing on the topic of 'one-dimensional kinematics' in an open-ended format. Following each problem was a question about student's perceptions about the problem they solved. The purpose of these questions was to confirm what kind of problem appears to be easy or difficult for the first-year student. As the researcher is not familiar with the ability of problem-solving among the first-year Physics Education students. The question following each problem is: (a) According to you, this problem is: (a) Very Easy, (b) Easy, (c) Intermediate, (d) Difficult but solvable, (e) I could not solve it (Appendix C). For this study, in this pilot testing the researcher focused on problem solving process rather than the students' knowledge of Kinematics topic, however, this does not mean that knowledge is less important.

According to pilot testing result, majority of students found that short problems which require one or two simple arithmetic of one-dimensional kinematics formula are easy (Appendix C, Problem No. 1, 2 and 3), while problems that require more than one arithmetic and a correct interpretation of one-dimensional kinematics concepts to reach the final answer were perceived as intermediate level by five students and the other four students found it difficult but solvable (Appendix C, Problem 4). The novel-like problems which include the real situation and require multi-steps and interpretations for reaching the solution appear to be difficult but solvable for half of the students while the others could not solve it (Appendix C, Problem No. 5, 6, 7 and 8). Finally, the researcher chose only seven problems that will be used for the study, as the for the warm-up just need one or two problems. The problem divided into two problems for the selection test, two warm-up problems and three problems for the think-aloud session.

3.4.1 Selection Test Problem

Selection test problems intended to help the researcher discover which students meet the basic criteria to become the participants for this study and doing the think-aloud session. The basic criterion was perceiving the problem given as difficult and do not have an automatic answer to the problem. Therefore, the problem for the selection test should have a similar level of difficulty as the think aloud problem. Based on the pilot testing, Problem 4 and 5 used as the selection test problem. Problem 4 and Problem 5 were a benchmark for the selection of the participants for think-aloud session. A student was selected to be a participant for the think-aloud session if she/he could solve problem 4 and 5 correctly, but perceived the problem given as difficult and had no immediate answer. These problems were adopted from Bueche (2006) and Young and Freedman (2002), the Physics course textbook of university students. Every problem was followed by a couple of questions about the students' view about the problem they solved, they are: (a) Do you think this is difficult for you? Please explain. (b) Do you have any immediate answer for this problem? The questions aim to help the researcher discover which students meet the criteria to be a participant for the think-aloud session. (see Appendix D for Selection test Problem).

3.4.2 'Warm-up' Problem

The warm-up problem at the beginning was used for students to begin thinking aloud automatically and without difficulty. Van Someren, Barnard, & Sandberg (1994) proposed that practice is essential in think-aloud, not just to train the student but for the researcher to correct the subject if they begin to interpret their thoughts as opposed to verbalising them.

Ericsson and Simon (1980) believed that a simple question that requires an easy arithmetic equation can be a warm-up task before think aloud session because it requires little effort to think aloud. As Ericsson and Simon (1980) suggest, a well-structured problem of one-dimensional kinematics topic was chosen to settle the student and help them gain confidence in the procedure and environment. Based on pilot testing, students find this problem is easy (Appendix C, Problem No 1 and 2). These problems were adapted from Phang (2009) with slightly minor adjustments (change of pronoun, to make students understand the problems easily).

3.4.3 Think-aloud Problem

According to Charters (2003), the selection process of task problem for a think aloud needs to be done carefully because task problem will affect the think-aloud process and data collected. The problem chosen for think-aloud should fit the criteria that are suggested by scholars and researchers before, they are:

1. The problem is the 'real' problem to the participants (Scoenfeld, 1992; Charters, 2003; Phang, 2009; Kuzzle, 2011; Zhang, 2014). It means the problem is not too difficult and not too easy for the participants. Ericsson & Simon (1980) stated that difficult task demand 'high cognitive load' which interferes the verbalisation during think aloud. but then, an easy task or if the process of resolving the problem is so straightforward may also be unsuitable, as it makes the problem solving lose its significance because the answer is merely called back from long term memory, then the situation is not considered as presenting a real problem (Kinskey, 2018). Phang (2009) who conducted the study to investigate metacognition in problem solving also stated that the selected problems for think aloud should be in intermediate level, it can not be a difficult task that the informant cannot give a complete the problem solving. Then again, it should not too easy that they can be solved in an automated manner.
2. The problems cover content in the target concept, and solutions should not require concepts and skills that participants have not learned in their college course to allow them to carry out the problem solving profitably. The problems in this study cover physics content in one-dimensional kinematics as the target concept. Kinematics holds a fundamental role in physics, any improvement in students' skills in this topic possibly improve understanding

of the rest of physics concepts that Because of the fundamental nature of kinematics in the whole of physics, any in student understanding of these concepts creates the possibility of an improved understanding of almost all of the rest of the physics concepts that students will learn throughout their study (Archambault et al., 2008).

Based on pilot testing, three problems which majority of students perceived as difficult but solvable were chosen (Appendix C, Problem No 6, 7, and 8) for the think-aloud session.

1. Main Problem One.

Bella, Cindy, Dahlia and Annisa will join 100 m x 4 (each runs 100 m) relay. Bella can finish a 100 m race in 25 s, Cindy can finish a 800 m race in 160 s and Chris can finish a 1500 m race in 500 s. The record of the 100 m x 4 relay in school is 89.9 s. Bella is the first runner of the team, followed by Cindy and Dahlia. If they all run at their usual speed as above, Annisa as the last runner, how fast should Annisa run, at least to beat 0.1 s of the record (0.1 s faster than the record)?

This question was adopted from Phang (2009) with minor adjustments (change of pronoun, to make students understand the problems easily). The problem is a multi-step, it is also not necessarily clear from the question which kinematics concepts would be most useful. The best approach to this question is to find the speed of each runner, the second step is to find the time of each runner to complete 100 m race, then calculate the remaining time Annisa has to complete the race and last step is to find the required speed of Annisa to break the record using the equation of linear motion.

2. Main Problem Two

A lorry moved to the East from stationary until it reached a constant speed of 50.0 m/s in 20.0 seconds. A car was moving with an acceleration of 4.0 m/s^2 to the West in 10.0 second from the starting point. The car moved into the lorry's lane in order to cross a car in front of it. When both the lorry and the car were in a distance of 500.0 m opposite to each other, they stepped on the brake immediately. The lorry took 10.0 seconds to stop while the car took 5.0 seconds to stop. Will there be any road accident happening? Why?

A multi-step question with a final correct answer was chosen as the second main question. The problem was adopted from Phang (2009). One approach to solve this question is using the uniformly accelerated motion formula.

3. Main Problem Three

Ari went to her cousin apartment at 15th (count from ground floor, first floor, second floor and so on), which way will be faster for Ari: a. Using stair with situation: Ari's velocity of running up stair is 4.0 m/s for the first 10.0 s. And he decelerate 0.2 m/s^2 after that. b. Using lift with situation: the velocity of the lift is 6.0 m/s or $1\frac{1}{2}$ floors per second, as the height of each floor is 4.0 m. And he always have to wait for 10.0 s for the lift to come to the ground floor.

A contextualised problem with the multi-step solution was chosen as the final main question. This question was adapted from Phang (2009) with minor adjustments. One approach to solve this question is to calculate the time if Ari chooses the stair or the lift.

As the purpose of this research is not to test the participant's knowledge, during the pilot study, selection test and think-aloud session, the researcher did not focus on students' knowledge in one-dimensional kinematics but the problem solving process. Furthermore, the problems used in this study do not serve as an instrument of study but as a *tool* for the researcher to select the participant and enable the researcher to observe one-dimensional kinematics problem solving process (Phang, 2006).

3.5 Pilot Study

In preparing for designing this study, a small pilot study was performed by the researcher with one Physics degree student. This pilot study was aimed to gain experiences for the actual process of data collection of the study. As it will be the first time for the researcher to employ think aloud and retrospective interview to collect the data. The pilot study also aimed to ensure that the interview questions were understood and prevent misunderstanding in interpreting the meaning of the questions after the translation. In the pilot study, the student was given a form (Appendix D) and instructed to solve three given problem and verbalise her thought during the problem solving process. When the student solved the problem, the researcher was observing and taking note of the student's behaviour. After the student solved each problem, the retrospective interview was performed.

The pilot study results helped in preparing the data collection method in this study. A few points were taken after the pilot study, they are:

- An exercise is needed before the think-aloud session, as the student could not perform think-aloud automatically.
- During think-aloud, there were times when students focused on the task and stop to think-aloud. Therefore, if something like this happens, the researcher needs to say 'please keep talking'.
- The interview questions were understood by the student.
- The pilot study helped in getting experience as a researcher. During the pilot study, the researcher noticed her weakness which was the difficulties to

observe the subject and elicit the question for retrospective interview from what subject did while solving the problem.

3.6 Selection of Participants

The purposive sampling strategy was utilised in this study. According to Ary et al. (2006), purposive samples is selected by qualitative researchers as they believe it is enough to provide maximum information for their research. The participant in this study was selected from a population of first-year Physics Education students at one university in Aceh, Indonesia. First-year students were chosen to minimize the possibility of occurrence lack of domain knowledge in the target concept. The target concept of this study is one-dimensional kinematics which is one of the topics in Basic Physics course. Physics Education students take this course when they are in the first semester of university. If the participants are chosen from the older year, there is a possibility they could no longer remember the equations.

The basic criteria for choosing participant in this study were based on the four following conditions that suggested by Kuzle (2011) and Zhang (2014) who also conducted a study to investigate metacognitive behaviour, they are:

1) the participants were willing to take part in this study and had signed the consent forms (Appendix G);
2) the participants have taken a college course (Basic Physics: *Fisika Dasar*) that related to the topic in this study (One-dimensional Kinematics);
3) the participants were comfortable with the problem solving activity (having adequate problem solving skill);
4) based on the data collection method in this study which will use think-aloud, it would be ideal if the participants are reflective thinkers who articulated their thinking well.

The selection process began with first-year students completed the selection test problems (Appendix F). Based on the students' answer to the selection test problems, then consider the criteria above, the participants for this study were selected. The participants of this study are six first-year students from the Physics education program. For the study which seek understand for phenomena, Creswell (2014) recommends 5-25 participants and Morse (1994) suggests at least six. The number of participants in this study also considers similar research before (e.g., Phang, 2006; Kuzle, 2011, Zhang, 2014) which collected data from two to six subjects.

3.7 Research Procedures

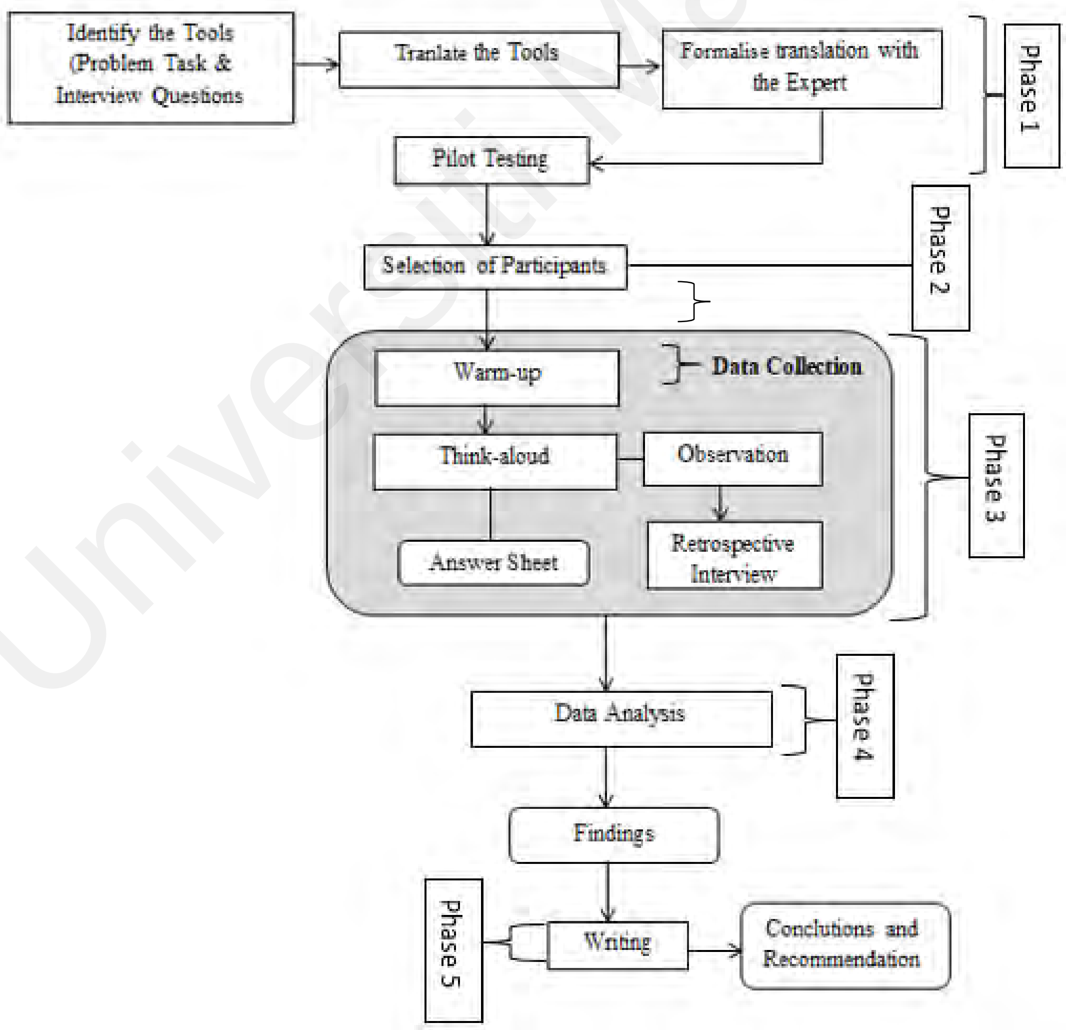


Figure 3.1 Research Procedure

There are five phases in this study which began with identifying the data collection tools utilised in this study. The tools selection used to collect the data is an important part of the research process. After located the tools for this study (problem task and interview questions), the researcher asked permission to use the tools in this study, then the tools were back-translated into the targeted participant's language (Bahasa Indonesia). The translation then formalises to the expert to get the approval and feedback. After got the approval and feedback, the pilot testing of the problem task was conducted.

This pilot testing aimed to ensure that the researcher has the appropriate tool for selection test and think-aloud session and to prevent students' misunderstanding in interpreting the meaning of the problems and questions after the translation. Based on the data from pilot testing, the problems then divided into selection test problems, warm-up problems, and think-aloud problems.

The second phase was the selection of participants. Thirty-seven first-year students participated in the selection test. There are thirty-one female students and six male students. They were given the selection test form and instructed to solve the selection test problems. They also instructed to answer the following questions of the selection test ((a) Do you think the problem is difficult for you? Please explain. (b) Do you have any immediate solution for this problem?)). After the students completed the selection test, the researcher analysed each of their solution and answer form. The students who solved the selection test problem correctly, but perceived the problem given as difficult and had no immediate answer were chosen as the participants that fit the criteria for the think-aloud session. Coincidentally the students that meet the criteria for think aloud session were all female students. Table 3.1 shows the six students Physics Education selected for the think-aloud session.

Tabel 3.1

The Selected Participants of the Study

Student	Name (Assumed)	Year	Gender
1	Tara	1	Female
2	Dayu	1	Female
3	Fela	1	Female
4	Reva	1	Female
5	Meri	1	Female
6	Nina	1	Female

After the participants for think-aloud session were selected, the third phase was the data collection process, an in-depth investigation using think aloud and an interview was carried out. Before the think-aloud session carried out individually, the researcher met with six students who were chosen as participants for think-aloud session. This meeting aimed to explain the research and what the participants' role in this study. The researcher asked the students' willingness to participate in this study and explained what is their role in this study. During the meeting, the researcher also held a brief think aloud training by explained what is think aloud, the think aloud instruction and provide a short think-aloud video to show the students what they are expected to do. At the end of the meeting, the researcher and each participant agreed on the terms of schedule to collect the data. The schedules for think-aloud session were made with each of six students individually. When setting up the schedule for think aloud session, all of the students preferred to solve three problems and do think aloud in one session as they are first-year students in university who have a tight schedule. Table 3.2 shows the schedule of students' think-aloud session.

Table 3.2

Schedule of Think-aloud Session

Students	Think-aloud Session
Meri	Thursday, 11th April 2019
Fela	Friday, 12th April 2019
Nina	Tuesday, 16th April 2019
Tara	Thursday, 18th April 2019
Dayu	Friday, 19th April 2019
Reva	Monday, 22nd April 2019

On the day of think aloud conducted, before started the each of think-aloud session with the participant, the researcher continued the think aloud training by conducting a short practice where the participant was asked to solve the warm-up problem and do think aloud. There are two warm-up problems, if the participant was confident to do think aloud after practice with one problem, the think aloud will be started, if not then she could practice again with another warm-up problem before think-aloud started. In the think-aloud session, each of the participants was given three problems. All the instruction during think-aloud session is the same for each of the participants. They were instructed to solve the problem and verbalize anything that comes to her mind, while the researcher observed the participants as she solved the problem by thinking aloud. During the observation, the researcher made remarks on students' behaviour while solving the problem. The researcher confirmed the remarks during the retrospective interview. The retrospective interview was conducted after the participants finished the problem solving for each problem.

These process repeated for other participants as well. The whole process was recorded by an audio recorder.

The fourth phase is analysing the data. Generally, data were analysed following Miles and Hubberman (1994) procedures. Starting from reducted the data, displayed the data and concluded the result. Before the analysis, the process of acquainted with the dataset by noted the initial comments and ideas on the transcription of students' problem solving process was carried out. Then the process of coding will take place (more discussion in the following section 3.8). The last phase will be writing. This phase includes reported the finding and make a conclusion, implications, and recommendations.

3.8 Data Analysis Technique

Data analysis is the process of concluding the data collected in the research site to create the conception of a phenomenon. According to McMillan & Schumacher (2006), qualitative data analysis is a systematic process that aims to explain a single phenomenon under scrutiny by doing the coding, categorizing, and interpreting data. They also argued that there is no specific right procedure to analyse qualitative data, the data can be analysed in any number of procedures. Each researcher must find his/her own way of analysing the data. The data analysis in this study was done manually. Although the data analysis process is not easily described because it was an ongoing process, the data analysis in this study generally following Miles & Huberman (1994) data analysis, which involves three procedures:

1) Data reduction;

According to Miles & Huberman (1994), data reduction is the process of selecting, focusing, fragmenting, and transforming the raw data in the transcript or field notes. This procedure will involve the process of reducing and organising the data collected at the research site such as transcripts, field notes, document, etc by coding, summarising, or putting away irrelevant data.

In this study, data reduction carried out through the process of coding the data. Coding is the process of labelling the raw data into a categorical tag. As Miles and Huberman (1994, p.56) pointed, “Codes are a mark that the researcher made for assigning data units of meaning to the descriptive information compiled during a study.” Codes are usually affiliated to ‘chunks’ of words, phrases, sentences or a whole paragraph.

2) Data display

Miles & Huberman (1994, p24) stated that this procedure is “process of gathering the data that allows the researcher to draw a conclusion or take action”. Miles and Huberman suggest that data can be organised by display it in the form of tables, context chart, event-state flowchart and other graphic formats. According to Biddle, Markland, Gilbourne, Chatzisarantis & Sparkes (2001), organising coded data can be done by clustering similar coded data into one theme, thus similar units are grouped into the first-order category. The same process is then repeated with the other coded data units, which can be grouped into a second-order category and so on. In this study, after the process of coding, the data findings displayed in the tables. (Appendix J: Sample of Matrix Analysis).

3) Conclusion-drawing

The last procedure is conclusion-drawing. Miles & Hubberman (1994) stated that this procedure involves concluding, determine what the data means, and note patterns, explanations, possible causative flows, and suggestions. They also pointed out one of the tactics of conclusion-drawing is subsumption particulars into the general or “bringing a pattern to them” (Miles & Hubberman, 1994, p27). In this study, the conclusion-drawing of data findings will address the research questions of the study.

3.8.1 Data Analysis Procedure

The process of analysing data in this study was divided into four phases. They are:

Organising and Familiarising Data. After the data was collected, the researcher organised the big amount of information from audiotaped think-aloud, audiotaped retrospective interview, observation field notes and answer sheet of six students. The researcher transcribed the recorded data into a typed file. Then the process of familiarisation with data set was conducted. In this process, the researcher immersed in data by listening to recorded data, reading the transcripts multiple times, studied the fieldnotes and written solution and noted the initial comments and ideas on the transcription.

Coding. The analysing continued with the process of coding. The coding process started with initial coding, where the think-aloud transcripts were openly analysed by applying gerunds, meaning labelled an action verb to participant's utterances that clearly defines the participant's behaviour within the utterance. So the length of any utterance coded was determined by what constituted a single behaviour. However, while examining these codes, attempts to define them clearly as behaviour students took during the problem solving process, it showed that a few codes are unclear and too broad to be useful. They may have constituted a 'single-behaviour' but not necessary a 'relevant single-behaviour'. For example, one behaviour has been coded as 'Reading', it turns out that majority of students do the reading with another act as a single behaviour such as reading *while also write information* or reading *while repeating the statement in her own word*. This suggested that the code might need to break down further. As the transcripts were examined again, and more refine codes was added. The example of attempts at coding the transcript could be seen in Figure 3.2.

Line	00.03	Intial Codes
1	Meaning Bella with distance 100, she can finish 25 s § Want to beat record § all the distance is .... Do each of them need to run 400 m?	Reading with strategy (strategy: make sense of the problem by rewording)/
2	Oh, this is relay. Then each of them need to finish 100 m.	Rewording
3	If they all run at their usual speed as above, Annisa as the last runner, how fast should Annisa run, to beat 0.1 s?	Reread

Figure 3.2 Initial codes of think aloud transcript

If the verbatim data from think aloud transcript is vague then the researcher also compared it with data sources from fieldnotes observation and participant's answer sheets. If the researcher needs to clarify students behaviour, the retrospective interview transcript was also used.

Remarks	Notes
1	First, Tara read the problem sentence by sentence while jotted down the information from the problem in Physics symbols.
2	After read the problem and write the information, she read the problem again and rewording the information from the problem

Figure 3.3 Fieldnotes

After coding entire students' transcription in one think-aloud verbatim transcript for each problem then the codes were aggregated together to get the list of behaviour that students exhibit while solving one-dimensional kinematics problems. Table 3.3 shows an example of coding of Tara. To avoid confusion, it is important to notes that few abbreviations were used in the tables, 'TA' represents Think aloud, 'RI' represents retrospective interview, 'FO' represents Fieldnotes Observation and '**Re**' represent line spoken by the researcher.

Table 3.3

Example Coding of Tara's think-aloud transcript

Excerpt From	Excerpt	Codes of Behaviour
FO-1	*Tara read the problem sentence by sentence while jotted down the information from the problem in Physics symbols.*	Reading with strategy *Note: strategy means that the participants reading while doing other action here the participants reading while jotted down the information.*
TA-1	Meaning Bella with distance 100, she can finish 25 s § Want to beat record § all the distance is .... Do each of them need to run 400 m?	Reading with strategy *(strategy: make sense of the problem by rewording)*
FO-2	*She read the problem again*	Rereading
TA-2	Oh, this is relay. Then each of them need to finish 100 m.	Reading with strategy *(strategy: rewording)*
TA-3	If they all run at their usual speed as above, Annisa as the last runner, how fast should Annisa run, to beat 0.1 s?	Rereading
TA-4	0.1 s faster than the record	Reading with strategy *(strategy: rewording)*
TA-5	What is asked is Annisa, Annisa's velocity	Emphasising the Goal
TA-6	Velocity § *v* is equal to *s* per *t*	Determining the formula
TA-7	The distance is same with others right? 100 m. *t* Annisa, how to get it? §	Deliberating what to do
TA-8	I think I need to calculate other's §	Formulating a plan
TA-9	Bella's § 100 divided by 25 is equal to 4	Making simple calculation
TA-10	Then Cindy's § 800 per 160 is equal to 5	
TA-11	Dahlia's § Dahlia's velocity is 3.	
TA-12	Then § But that is for different distance, time for distance 100 m	Breaking down the plan
TA-13	Bella's time § *v* is equal to *s* per *t*	Doing algebra calculation
TA-14	then *t* is equal to *s per v*	
TA-15	So Bella's time is 25 second	
TA-16	Oh...Bella's time already in the problem, because the distance is the same	
TA-17	Cindy's 100 divided by 5 is equal to 20	Making simple calculation
TA-18	Dahlia's 100 divided by 3 is equal to 33.33	
TA-19	then to get Annisa's § add all their time	Breaking down the plan

TA-20	25 plus 20 plus 33.3. 78,3	Making simple calculation
TA-21	Then §	
TA-22	89.9 § 89.9 minus 78.3. 11.6	
TA-23	11.6 is remaing time for Annisa	
TA-24	So *v* of Annisa, *v = s/t (wrote)*	Doing algebra calculation
TA-25	100 divided 11.6. 8.62	
FO-3	*After calculated Annisa's time, Tara looked back and forth at the answer she written and problem*	Assessing the computation
TA-26	I think I made mistake, can I go back and fixed it?	Recognising Error
Re	**Sure, go ahead**	
TA-27	Because they want to break the record at least 0.1, then the time should 89.8	Recognising Error
TA-28	89,8 minus 78.3. 11.5	Making simple calculation
TA-29	Then 100 divided 11.5. 8.69	
TA-30	So, Annisa's velocity is 8.69 m/s	Answering

Identifying Metacognitive Behaviour. To address the first research question, the researcher classified students' metacognitive behaviour from the initial codes. The classification of metacognitive behaviour was based on a metacognitive framework proposed by Yimer & Ellerton (2010). Table 3.4 lists the metacognitive behaviour exhibited during the problem solving process according to Yimer & Ellerton (2010).

Table 3.4

Metacognitive behaviour proposed by Yimer & Ellerton (2009)

Phase	Metacognitive Behaviour
Engagement	Jotting down the main ideas
	Making a drawing
	Making sense of the information
	Identifying key ideas relevant information for solving the problem
	Relating the information to a certain domain
	Assessing familiarity or recalling similar problems solved before
	Assessing degree of difficulty
	Assessing the necessary store of knowledge one has in relation to the problem
Transformation-formulation	Using specific cases or numbers to visualise the situation in the problem
	Conjecturing (based on specific observations and previous experiences)
	Reflecting on conjectures or explorations whether they are feasible or not
	Reflecting on conjectures wthether they are feasible or not
	Devising a strategy either to test conjectures or devising global or local plans
	Reflecting on the feasibility of the plan vis-à-vis the key features of the problem
Implemantation	Breaking down plan into manageable sub plans where necessary
	Assessing the plan with the condition and requirement set by the problem
	Reflecting on the appropriateness of actions
Evaluation	Rereading the problem to check whether the result has answered the question in the problem or not
	Assessing the planfor consistency with the key features as well as for possible errors in computation or analysis
	Assessing for reasonableness of result
	Making a decision to accept or reject a solution
Internalisation	Reflecting on the entire solution process
	Identifying critical features in the process
	Evaluating the solution process for adaptability in other situations, different ways of solving it, and elegance
	Reflecting on the mathematical rigor involved, one's confidence in handling the process, and degree of satisfaction.

Then the identified metacognitive behaviour are categorised into five-phases: engagement, transformation-formulation, implementation, evaluation and internalisation. Engagement phase is a phase where the behaviour of problem solver involves making initial confrontation with the problem. In this phase, problem-solver demonstrates the behaviour that intends to understand the problem. Transformation-formulation is a phase where the behaviour problem solver transforms from initial understanding to exploratory and plan how to solve the problem. The implementation phase involves behaviour that aims to monitor the action while implementing the plan. Evaluation involves judgment of problem solver towards her action, her plan and her solution. Internalisation is a phase where the problem solver reflects on the entire problem solving process. Table 3.5 shows an example of the identification and categorisation of metacognitive behaviour.

Table 3.5

Example of Identification of Metacognitive Behaviour

Excerpt From	Excerpt	Codes of Behaviour	Phase
FO-1	*Tara read the problem sentence by sentence while jotted down the information from the problem in Physics symbols.*	Reading with strategy *Note: strategy means that the participants reading while doing other action here the participants reading while jotted down the information.*	Engagement
TA-1	Meaning Bella with distance 100, she can finish 25 s § Want to beat record § all the distance is .... Do each of them need to run 400 m?	Reading with strategy *(strategy: make sense of the problem by rewording)*	
FO-2	*She read the problem again*	Rereading	
TA-2	Oh, this is relay. Then each of them need to finish 100 m.	Reading with strategy *(strategy: rewording)*	
TA-3	If they all run at their usual speed as above, Annisa as the last runner, how fast should Annisa run, to beat 0.1 s?	Rereading	
TA-4	0.1 s faster than the record	Reading with strategy *(strategy: rewording)*	
TA-5	What is asked is Annisa,	Emphasising the	

	Annisa's velocity	Goal	
TA-6	Velocity § *v* is equal to *s* per *t*	Determining the formula	
TA-7	The distance is same with others right? 100 m. *t* Annisa, how to get it? §	Deliberating what to do	
TA-8	I think I need to calculate other's §	Formulating a plan	Transformation-formulation
TA-9	Bella's § 100 divided by 25 is equal to 4	Making simple calculation	
TA-10	Then Cindy's § 800 per 160 is equal to 5		
TA-11	Dahlia's § Dahlia's velocity is 3.		
TA-12	Then § But that is for different distance, time for distance 100 m	Breaking down the plan	Implementation
TA-13	Bella's time § *v* is equal to *s* per *t*	Doing algebra calculation	
TA-14	then *t* is equal to *s per v*		
TA-15	So Bella's time is 25 second		
TA-16	Oh...Bella's time already in the problem, because the distance is the same		
TA-17	Cindy's 100 divided by 5 is equal to 20	Making simple calculation	
TA-18	Dahlia's 100 divided by 3 is equal to 33.33		
TA-19	then to get Annisa's § add all their time	Breaking down the plan	Implementation
TA-20	25 plus 20 plus 33.3. 78,3	Making simple calculation	
TA-21	Then §		
TA-22	89.9 § 89.9 minus 78.3. 11.6		
TA-23	11.6 is remaing time for Annisa		
TA-24	So *v* of Annisa, *v* = *s/t* *(wrote)*	Doing algebra calculation	

TA-25	100 divided 11.6. 8.62		
FO-3	*After calculated Annisa's time, Tara looked back and forth at the answer she written and problem*	Assessing the computation	Evaluation
TA-26	I think I made mistake, can I go back and fixed it?	Recognising Error	
Re	**Sure, go ahead**		
TA-27	Because they want to break the record at least 0.1, then the time should 89.8	Recognising Error	
TA-28	89,8 minus 78.3. 11.5	Making simple calculation	
TA-29	Then 100 divided 11.5. 8.69		
TA-30	So, Annisa's velocity is 8.69 m/s	Answering	

Examining Role of Metacognition. To answer the second research question which addressed the role of metacognition in problem solving process of one-dimensional kinematics the researcher scrutinised the uses of metacognitive behaviour in problem solving and how it helps the students completed their problem solving. The analysis process is done by labelled metacognitive behaviours from analysis of the previous research question, then the researcher looked for the consistency of metacognitive behaviours demonstration in each students' problem solving for all three problems (Table 3.6) and analysing how the metacognitive behaviours help the students completed their problem solving, what is the different consequences found in the problem solving result between students who exhibited metacognitive behaviour and who did not.

Table 3.6

Distribution of Metacognitive Behaviour Exhibited by Students during Problem Solving Process

Metacognitive Behaviour	Tara			Dayu			Fela			Reva			Meri			Nina		
	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
Rereading	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Reading with strategy	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Arrange information	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Draw a sketch											●						●	
Making sense of the information	●	●	●	●	●		●	●								●	●	●
Relating concept					●			●									●	●
Making Conjecture		●									(shaded)							
Formulating Plan	●	●		●	●	●	●	●			(shaded)				●	●	●	●
Breaking down the plan	●	●	(shaded)	●	●	●		●	(shaded)		(shaded)					●	●	●
Assessing plan	●	●	(shaded)	●	●	●		●	(shaded)		(shaded)					●	●	●
Reflecting on plan		●	(shaded)						(shaded)		(shaded)						●	
Assessing computation	●	●	(shaded)	●	●	●			(shaded)		(shaded)					●	●	●
Solution	√	√	(shaded)	√	√	√	X	√	(shaded)	X	(shaded)	X	X	X	√	√	√	√

Note.

P1	Problem 1
●	Student exhibited metacognitive behaviour
(white box)	Student did not exhibit metacognitive behaviour
√	Student gives the correct answer
X	Student gives the wrong answer
(shaded box)	Student could not complete the problem solving

Table 3.6 shows the number of metacognitive behaviour exhibited by every student while solving one problem and the result of their problem solving performance. The table also shows some students exhibit more metacognitive behaviour than other students during problem solving process and presented the right answer for the problem. The analysis also considering students' reason behind each demonstrated behaviour by looking at retrospective interview transcript. The result of data analysis for every research question will be discussed further in the next chapter.

3.9 Trustworthiness of the Study

According to Macmillan and Schumacher (2001), the ultimate goal for good research is to provide a credible answer to the research question. This statement refers to data quality whether the data are valid and reliable. To ensure that, this section will discuss the trustworthiness of this study. Several techniques have been identified in the literature for enhancing the trustworthiness of the qualitative study. Table 3.8 showed the criteria and techniques to establish the trustworthiness of the qualitative study

Table 3.7

Criteria to establish trustworthiness

Criterion	Technique	Procedure
Credibility	Prolonged engagement	Spending enough time in the context
	Persistent observation	Focusing on an issue in detail
	Triangulation	Using multiple methods, sources, researchers or theories
	Peer debriefing	Exposing oneself to a disinterested peer in a manner paralleling an analytic session
	Negative case analysis	The process of revising hypotheses with hindsight
	Referential adequacy	Collecting holistic data (i.e., videotaping) to enable interpretation being tested for adequacy
	Member-check	Checking the analyses, interpretations, and conclusions with the respondents of the research.
Transferability	'Thick-description'	Bringing the readers to the context
Dependability	Triangulation	Using multiple methods, sources, researchers or theories
	Audit	Enabling auditing when required
Confirmability	Triangulation	Using multiple methods, sources, researchers or theories
	Audit	Enabling auditing when required

In this study, in establishing transferability, a 'thick description' (within the word-limitation) of the findings was reported. The thick description includes contextual information about the research sites and detail description of the phenomenon under the study. Shenton (2004) argued that thick description is important because it allows readers to have a thorough understanding of the phenomenon under investigation and enabling the reader to compare the cases that illustrated in the report with what they have seen emerge in other situations.

Then the triangulation was used to establish credibility, dependability and confirmability. According to Krefting (1991) triangulation is a great strategy to ensure the quality of the research. Ary (et al., 2006) stated that the employment of triangulation often led to support or contradict the interpretation evidence which further strengthened the trustworthiness of the findings. Triangulation can be achieved by employing different procedures and instruments to collect the same data from the same sample. In this research, a combination of the result of think-aloud protocol, retrospective interview, observation and analysis of answer sheets from participants was used as data triangulation. The overall participants' thought and situation during the problem solving process were examined based on the reports of six participants collected in the context of three series of problems at different points in time.

3.10 Ethical Consideration

Following the ethical standards in planning and conducting the research is important (Ary et. al., 2006). While carrying out this study, a few points need to be considered, they are:

1. Getting permission to conduct the research. The permission was requested from the dean of Education Faculty through formal letters.

2. The willingness of the participants. The explanation was given to the participants before the data was collected. They were informed about the recording of their voice during think aloud and who may be listening to it. They also were informed about what they should do, and how long it would take. Students also were given the option of withdrawing if they do not agree to take part in this study. They were asked to fill in a consent form if they agreed to participate (see Appendix D).

3. Confidentiality. The university's and students' names were not reported in the writing. Pseudonyms were used for the participants.

3.11 Summary

This chapter describes the methodology employed in this study. The researcher adopted a qualitative research method to fulfil the aim of this study. The data collection techniques were think aloud technique, observation, retrospective interview, and document analysis. The sample was selected based on purposive sampling. The research involves six first-year Physics Education students from a university in Aceh. The finding of the research described in the next chapter.

CHAPTER 4

FINDINGS

4.1 Introduction of the Chapter

This study investigated students' metacognition when they attempt to solve one-dimensional kinematics problem. There are two research questions addressed by this study:

1. What are metacognitive behaviours that students exhibit while solving one-dimensional kinematics problem?
2. What is the role of metacognition in the problem solving process of one-dimensional kinematics?

This chapter presents the findings of this study and cites evidence obtained from the collected data. This chapter begins with the overview of students' attempt at one-dimensional kinematics problems then the following section lists students' behaviours while solving the problems from reading the problem until they get the answer. In the next section, the behaviours that inference metacognition characteristic will be separated and discussed; and how these behaviour support students to complete problem solving also will be discussed which will answer the second research question, the role of metacognition in problem solving process of one-dimensional kinematics.

In order to answer the research questions, data collected from six students during the study includes the think-aloud transcripts, observation field notes during the think aloud session, retrospective semi-structured interview transcripts, and students' answer sheets were analysed qualitatively and reported in the following section. The reported findings are supported by excerpts from various data. In the excerpts from transcripts, various abbreviations were used to denote the sources of the data. To avoid confusion, 'Problem' is used to refer to the one-dimensional kinematics problems given to the students. 'Q' refers to questions and answers (e.g., Q35) recorded during the retrospective semi-structured interviews. The brackets with numbers only indicate the line numbers of the sentence (e.g., (45) or (46-55)) in the thinking-aloud transcripts and as in appendices. For the fieldnotes excerpts which were consist of remarks made by the researcher, the letter R followed by a number (e.g., R1) indicates to the 'first remark'. For the student, the used abbreviation follows the first letter of the students' assumed name such as T (Tara), D (Dayu), Fela (F), Reva (R), M (Meri) and N (Nina). The other used abbreviations follow the conventions below:

TA represents Think-aloud

RI represents Retrospective Interview

FO represents Fieldnotes Observation

AS represent Answer Sheet

4.2 Overview of Students' Attempt at One-dimensional Kinematics Problems

This section provides a descriptive overview of students' attempt to solve the problems and detailed students' behaviour while solving one-dimensional kinematics problem. Table 4.1 shows the number of problems solved by students in think-aloud session.

Table 4.1

Problems solved by each student in the think-aloud session

Participants	Problem		
	1	2	3
Tara	√	√	
Dayu	√	√	√
Fela	X	√	
Reva	X		X
Meri	X	X	√
Nina	√	√	√

Note.

[ ] = student could not give the complete solution

[√] = student gives the correct answer

[X] = student gives a wrong answer

The students' problem solving processes for the three problems observed either through what they said or their behaviour while solving problems. In what follows, the overview of students' attempt at solving one-dimensional kinematics problems is presented.

4.2.1 Tara

Tara solved problem 1 and 2 but she could not solve problem number 3 completely. She perceived that all the problems were difficult (RI_T: Q2, Q16, Q26). Tara started her engagement with the problem by reading the problem while wrote the information from the problem in Physics symbols and saying the meaning of the problem. After she had read the problem and arranged all the information she thought important, she read back the problem statement. Then she started to consider which formula she should use to solve the problem and what she should do next. She would take time to deliberate while keep looking at her arranged information and saying what she planned to do to solve them. While she is computing the answer for problem 1, she made a mistake but immediately realised and fixed it.

Generally, Tara presented the same steps for problem 2, except after she read the problem and arranged information, she drew a sketch to illustrate the problem situation. As she said that this problem was more difficult than the first problem, she was not sure which formula to use, so she took the time to decide the formula. For problem 3, although she could not give a complete solution to problem 3, the steps she took in the initial was similar with the other problem until she gave up and said she could not solve it. During the retrospective interview, Tara stated that she felt kinematics is challenging, she did not like the topic because she did not master the topic.

4.2.2 Dayu

Dayu solved three problems while doing the think aloud. The two of the problems were perceived as challenging while the other one was difficult. For problem 1 and 2, Dayu also read the problem sentence by sentence while arranged the information from the problem into Physics symbols then planned how to solve them. After that, she planned the first step she should do. Then carrying out the plan by doing the calculation. She carried out the plan unsurely as can be seen from her behaviour while she continued to look back at her calculation before she proceeded with the further plan. While looking back at her calculation, she noticed that she made a wrong calculation, she immediately fixed her calculation. It happened a few times, Dayu always examines her calculation every time she had done one, and this behaviour allows her to realise immediately the mistake she made in calculation.

However, Dayu addressed problem 3 in a slightly different way, after reading the problem and found the information, she immediately executed the first calculation, then read the problem again, doing the planning, deliberating formula and calculate again until she reached the final answer. However, she still does the constant checking every time she had finished the calculation. Her behaviour of checking the answers can be seen in three the problems, especially in the middle of the calculation. In her answer sheets for Problem 1 and 2, there were several corrections that she made to her calculations and answers. During the retrospective interview, Dayu said that she did not like the topic and think her problem solving skill for one-dimensional kinematics topic is in intermediate level, but she memorised all of the formula one-dimensional kinematics.

4.2.3 Fela

Fela solved all of three problems. She perceived problem 1 as easy, problem 2 as challenging while problem 3 is difficult (RI_F: Q1, Q14 & Q24). Fela problem solving steps depended by how she perceived the problem. For problem 1, she said it was easy, so she first read the problems and interpreted it in her own words then she executed the first calculation even before she finished reading the problem; then she read again, analysing, calculating until she reached the final answer. During the interview, she said she doing that to save time. Fela's way to solve the problem is somewhat similar to Dayu's problem solving in Problem 3, the difference was Fela do not look back to check her calculation or her work.

For problem 2 which she perceived as challenging. After she read the problem and arranged all the information, she read back the problem while trying to analyse and planned what she should do. She then executed the first calculation and made another plan the calculate again until she got the final answer.

3.	v_t is equal to v_o plus a times t. v_t squared is equal to the square of v_0 plus *2* times a times s. s is equal to v_0 times t plus a half times a times t squared	Write all the formula she memorize
4.	First § Here I need to find both 's' of lorry and car.	Determining next step
5.	s_{lorry} § s is equal to v_0 times t plus a half times a times t squared § But there is no a. It means I need to find a?	Deliberating sub-goal and formula
6.	Find a with § Try use this v_t is equal to v_o plus a times t	Determining sub goal and formula
7.	v_t is § 50. Zero plus a times t. t is 20. a equals to 50 divided by 20. a is 2.5	Algebra calculation
8.	Now calculate the s	Next step
9.	s is § s is equal to v_0 times t plus a half times a times t squared. v_0 is zero, t is § Means zero times t is equals to zero.	Calculating algebra while.
10.	Wait § The v_0 § Not zero, right? I think it's 50. Because v when it'll stop.	Deliberating the variable
11.	I try it, I can change it later if it wrong. 50 times t to stop. 50 times 10 Plus a half. a is 25 times 10. 10 times 10 is 100. 100 divided by 2 is 50. 50 times 2.5. 125. 500 plus 125. Is 625 metre.	Carrying the calculation unsurely
12.	Now car § t check. a check. There is no v_t.	Look at current situation
13.	So find v_t first §	Sub-goal
14.	v_t is equal to v_o plus a times t. v_o is zero because starting point. Means zero plus 4 times 10. § v_t is 40.	Algebra calculation
15.	Put this to s formula. s is equal to v_0 times t plus a half times a times t squared. So 40 times t plus a half times 4 times t. t is § t is 5. 40 times 5 200. Plus 5 times 5 is 25. 25 times 4. 100. 100 divided by 2 is 50.	
16.	200 plus 50 is 250 metre. Then s_{total} is 625 plus 250 metre. 875 metre	Simple calculation
17.	less so there is no crash. Will there be an accident? No because the distance found is less than the distance between	Stating answer

(TA_F, Problem 2)

Fela was always found to arrange all the information given in the problem after she read the problem. Not only information from the problem, but Fela also listed formula of one-dimensional kinematics that she memorized. From her interview, Fela said it is important for her as she could refer to the information quickly and related one information with another to figure out the answer RI_F: Q8 & Q17). From her answer sheets, it is clear that Fela wrote down all the information from the problem. While she was executing her plans and came to an answer for Problem 2, she often looked back to check her steps. During the retrospective interview, Fela said she likes the topic but she is not confidence at her skill to solve the one-dimensional kinematics problem.

4.2.4 Reva

Reva gave a complete solution for two problems (Problem 1 and Problem 3) as she could not give a solution for Problem 2. Unfortunately, she gave the wrong solution for both Problem 1 and Problem 3. Problem 1 was perceived as easy while problem 3 was perceived as a moderate level, and Problem 2 is difficult (RI_R, Q10). For problem 1 and 3, Reva started solving the problem by reading the problem while wrote down the information from the problem and saying the meaning of the problem in her own word. After stated what the problem asked, she immediately executed the calculation. After she has done with the first calculation, she was not certain about the result. However, she ignored the fact that her answer is not logic and continue the calculation. At last, she gave the wrong solution. Reva solved the problem faster than other students. During the retrospective interview, Reva viewed her problem-solving skill in one-dimensional topic is reliable.

4.2.5 Meri

Meri gave the complete solution for three problems however, she gave the wrong answer for Problem 2. She was quite confident to do think-aloud during the problem solving process. She perceived that all of the problems were difficult but solvable (RI_M: Q1, Q15 & Q24). Like the majority of students, Meri started her problem solving by reading the problem. After reading, she rewording the statement in the problem in her own word then wrote down the information from the problem. After that she said her plan for the next step, then she did the computation until she got the final answer. Meri's attempt to solve one-dimensional kinematics is likely 'text-book' problem solving.

However, in Problem 2, she read the problems and then immediately do computation without taking time to analyse the situation in the problem. She also did not check her work. During the retrospective interview, Meri said that she is not good at solving one-dimensional kinematics topic but she likes the topic.

4.2.6 Nina

Nina solved all the problems. She perceived that Problem 1 was easy while Problem 2 and Problem 3 were difficult (RI_N: Q1, Q13 & Q21). Nina began all her problem solving by reading the problem statement, wrote the given values as she encounters them in the statement. During solving Problem 1, after she read the problems and wrote all the information in Physics symbols, she stating her whole plan to solve the problem. Immediately after saying what she needs to do, Nina proceeds to execute her plan by executed the subgoal one by one. She did the calculation, deliberated about the formula, next step, variables and decide the what she need to do simultaneously. She also keeps tracking what she had done, the action reflecting in her think-aloud. The checking action helped her to discover the mistake in her calculation and choose another formula to solve the problem. During her retrospective interview, Nina expresses her feeling of kinematics problem solving. She revealed that she enjoys the problem solving process but sometimes, the difficulty of the problem made her frustrated. She also perceived her problem-solving skill is at the intermediate level.

Overview of students attempts at one-dimensional kinematics revealed students' problem solving process for each problem. To identified metacognitive behaviour and answer the first research question of this study, students' behaviour while attempted to solve one-dimensional kinematics problem solving was listed and then classified as metacognitive behaviour or not based on Yimer & Ellerton framework.

Table 4.2 listed all of the behaviour that students' exhibited while solving one-dimensional kinematics problem. It is important to note that the behaviours are not listed as a chronological sequence because students' behaviours while solving the problem are not linear.

Table 4.2

Students' Behaviour while Solving One-Dimensional Kinematics Problem

Behaviour	**Description**
Reading	Student read a whole problem statement as the first single action.
Rereading	Student read back the problem to understand the problem further or read the chunks of the problem in the middle of the problem solving process to find some clues.
Reading with strategy	Student read the problem and at the same time trying to understand the problem by rewording, making representation such as drawing, arranging information, or directly calculate the information given.
Arranging Information	Student organise the information given in the problem while analysing the problem; they either underlined it, jotted it down or arranged it neatly as a list
Making sense of the problem	Student tried to understand the problems situation by rewording the problem statement, presenting them in different ways, words, or symbols
Drawing a Sketch	Student make a sketch to understand the problem situation
Listing Prior Knowledge	Student write down the prior knowledge she has such as formula that she remembered
Emphasising the Goal	Student rewording what is asked in the problem
Determining the Formula	Student deciding which formula to use

Determining the variable	Student decide the variable they must use in the equation
Formulate the plan	Students generated a gradual plan on how to deal with the problem.
Breaking down the plan	Student making any kind of brief planning between the first and the following calculations.
Reflecting on the plan	Student making a judgement at her plan and modified the previous plan if needed.
Relating the concept	Student's efforts in finding or relating the relevant concepts to a problem.
Deliberating the Formula	Student carefully thought a possible formula by matching the variables found in the problem
Deliberating the Variable	Student carefully thought which variable she should put in the equation during computation
Assessing the plan	Student assesses her plan by analysing her current situation by looking at the variables she obtained from the problem and calculation
Recognising Error	Student realised that she made a mistake and tried to find or understand the mistake and how to make a correction
Making Simple Calculation	Student was making a calculation or computation without involving another thinking process.
Doing Algebra Calculation	Student was doing mathematical algebra to arrange a formula into a format that facilitated problem-solving.
Assessing the computation	Students to check their work (computation) if the result is correct or if the goal had been achieved
Reflecting on Oneself	Students made a remark about themselves
Speculating the answer	Students making speculation about the solution of the problem by saying the possible answer.
Answering	Student arrived at an answer at the end of the problem-solving steps and gave the final answer to the problem

- **Reading**

Result of data analysis showed that all of the students began their problem solving with reading as the first steps. 'Reading' was coded for the behaviour where the student read a whole problem statement as the first step while solving the problem. 'Reading' was found in all students problem solving. As an example, in Dayu' problem solving as illustrated in the following fieldnotes excerpt,

Dayu started by reading the problem statement.

(FO_D, Problem 3, R1)

And Tara's problem solving,

Pink: rewording in reading

Green: mumble while write down the information in reading

Tara - Problem 1

Line	00.03	Codes
1	Bella, Cindy, Dahlia and Annisa will join 100 m x 4 (each runs 100 m) relay . Bella can finish a 100 m race in 25 § Meaning Bella with distance 100, she can finish 25 s § Cindy can finish a 800 m race in 160 s. And Dahlia can finish a 1500 m race in 500 s Want to beat record § all the distance is .... Do each of them need to run 400 m?	First reading and at the same time also write the information and rewording the problem statement

(TA_T, Problem 1)

Although, all of the students started by reading the problem as the first step, later almost all of them were found to rereading the problem statement.

- **Rereading**

'Rereading' was coded for the behaviour where the student reading back the problem to understand the problem further. The code also included a behaviour which student was reading the chunks of the problem in the middle of the problem solving process to find some clues. Example of rereading was showed by excerpt below, it coded during Tara's problem solving process.

Pink: rewording in reading

Green: mumble while write down the information in reading

Tara - Problem 1

Line	00.03	Codes
1	Bella, Cindy, Dahlia and Annisa will join 100 m x 4 (each runs 100 m) relay . Bella can finish a 100 m race in 25 § Meaning Bella with distance 100, she can finish 25 s § Cindy can finish a 800 m race in 160 s. And Dahlia can finish a 1500 m race in 500 s Want to beat record § all the distance is .... Do each of them need to run 400 m?	First reading and at the same time also write the information and rewording the problem statement
2	Oh, this is relay. Then each of them need to finish 100 m.	Rewording the problem statement
3	If they all run at their usual speed as above, Annisa as the last runner, how fast should Annisa run, to beat 0.1 s?	Reading back

(TA_T, Problem 1)

The think aloud excerpt above shows that after finished the first reading and trying to understand the problem, Tara reading back the problem statement. Her behaviour was also noted in fieldnotes, as showed below:

After writing the information, she read the problem again then ......

(FO_T, Problem 1, R2)

Tara acknowledged her 'rereading' when she was asked to clarify her behaviour during the retrospective interview immediately after solving Problem 1. When she was asked why she reread the problem she said:

"All the problem is long, so I need to read it twice or more to understand it."

(RI_T, Q22)

The same behaviour also found in Dayu' problem solving process (Problem 1) and Nina's problem solving process (Problem 2).

Nina - Problem 2

Turquoise: mumble while draw a skecth

Green: mumble while write down the information in reading

Line	00.05	Initial codes
1.	A lorry moved to the East from stationary. Means the lorry's v_0 is zero. v_t is 50 m/s. t is 20 seconds. While a car was moving with an acceleration. a is equal to 4 m/s squared. To the West. This ... to the East. In 10 seconds from starting point. Car moved. The distance between loory and ...	Read the problem while write the informationa and draw sketch
2.	A lorry moved to the East	Reading back the whole problem statement

(TA_N, Problem 2)

When Dayu and Nina were asked about the reason for these students to read back the problem statement, their answer also similar to Tara's statement which was 'for further understanding and to find some clues'. For some students, rereading had become a habit when they encounter the problem, even though the question was easy. For example, Nina reread all the problems after the first reading despite Problems 1 being perceived as easy for her. She said that primarily the reason was to fully understand the problem.

- **Reading with Strategy**

This code refers to students' behaviour where student reading the problem statement but at the same time make another attempt to understand the problem by rewording, write down information given in the problem, making representation such as drawing sketch, or directly calculate the information given.

For example, Dayu while solving problem 2, after done the first reading, she read back the problem but not exactly the whole problem, she read a chunk of work then rather she reworded what she read in a statement that she could understand by changing the information from the problem into physics symbols,

> "A lorry moved to the East from stationary until it reached a constant speed of 50.0 m/s in 20.0 seconds. A car was moving with an acceleration of 4.0 m/s^2 to the West in 10.0 second from the starting point."
>
> (TA_D, Problem 2, 1)

> *v* of lorry is 50 metre per second. *t* of lorry is 20 seconds. *a* car is 4 metre per second squared. *t* car is 10 seconds."
>
> (TA_D, Problem 2, 2)

Lines 1 were the problem statement that she read word-by-word while line 2 was her own representation of the variable in the problem using physics symbols that made more sense to her and could help her grasp the important information.

Another strategy that students do to understand the problem while reading was by using an illustration. Two out of six students made a sketch to understand the situation in the problem. They are Reva and Nina, both of them made an illustration in for Problem 2.

> She also draws a sketch to illustrate the problem situation while reading
>
> (FO_R, Problem 2, R2)

> Then Nina read back the problem while attempt to draw an illustration of the situation in the problem.
>
> (FO_N, Problem 2, R2)

It was evident in the students' think-aloud transcript and answer sheet, that all of them made their own representation to interpretation the problem, by rewording the meaning of the problem, using the physics symbols and drawing an illustration.

Another attempt students made while reading is immediately calculating the information given in the problem even before finish reading the problem. This was coded in the case of Dayu in Problem 3 and Fela in Problem 1 and 3, as illustrated in the following think-aloud audio transcript,

> “ Bella, Cindy, Dahlia and Annisa will join 100-metre times 4 relay. Each of them will run for 100 metres. They are the mainstay athletes of the school. Bella can finish a 100 metres race in 25 seconds. Bella’s distance is 100 metres. While her time is 25 seconds.”
>
> (TA_F, Problem 1, 1)
>
> “So Bella’s velocity is. Then v is s divided by t. 100 metres divided by 25 seconds. Equals to 4 metre per second...”
>
> (TA_F, Problem 1, 3)

Line 1 was the problem statement that she read word-by-word while line 3 was her verbalism while calculating the first goal. The code was also found in the fieldnotes excerpt,

> Fela read the problem, write down a few information and immediately plan and calculate the first sub-goal.
>
> (FO_F, Problem 1, R1)

During the retrospective interview, when she was asked about her action, she said,

> “Umm, for me it’s easier, I usually do that in exam because it saving time. It’s impossible to read repeatedly if you have a short time.”
>
> (RI_F, Q6)

- **Arranging Information**

This code referred to behaviour where students organise the information given in the problem while analysing the problem; they either underlined it, jotted it down or arranged it neatly as a list. This was evident in all of the students' answer sheet and was seen as a strategy frequently used by them. During the analysis, there were two different ways that students use to keep track of the information. Most of the students preferred to write the information down (e.g., Tara, Dayu, Fela, Meri, and Nina) and the other underlined the information in the problem sheet (e.g., Reva).

> Tara read the problem while rewording and write down the information from the problem
>
> (FO_T, Problem 2, R1)
>
> Dayu read the problem while writing down the information.
>
> (FO_D, Problem 2, R2)
>
> She read the problem while underlined the information in problem sheet
>
> (FO_R, Problem 2, R1)

- **Making Sense of the Problem**

This code is referred to as behaviour where a student tried to understand the problems situation by rewording the problem statement or presenting them in different ways, words, or symbols. This action showed that the students made an effort to understand the problems. For example, Meri in solving Problem 1, read the problem then simplified it into her own words, saying:

> "There is distance, they join relay. It says 0.1 faster than 89.9."
>
> (TA_M, Problem 1, 2)

Another incident also found during Tara's problem solving. When Tara doubted the problem she reread the problem. When she was reading, rewording the statement from the problem to show her understanding,

> "Bella can finish a 100 m race in 25. So, Bella with distance 100, she can finish 25 s."
>
> (TA_T, Problem 1, 1)
>
> She said,
>
> ".....Oh, this is relay. Then each of them needs to finish 100 m."
>
> (TA_T, Problem 1, 2)

- **Drawing a Sketch**

The code refers to behaviour where students make a sketch to understand the problem situation. During the analysis, two out of six students were found making a sketch to understand the situation in the problem. They are Reva and Nina, both of them made an illustration in for Problem 2.

> She also draws a sketch to illustrate the problem situation while reading
>
> (FO_R, Problem 2, R2)

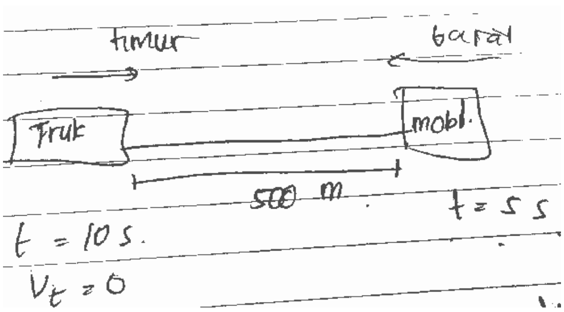


Figure 4.1 Reva's Sketch in Problem 2

- **Listing the Prior Knowledge**

'Listing the Prior Knowledge' referred to behaviour where a student writes down the prior knowledge she has such as formula that she remembered. It was only found in in the case of Fela, after arranging the information of the problem she wrote down all the formula of one-dimensional kinematics she remembered. During the retrospective interview, when she was asked about why she did that, she said,

> "I'm afraid I could not memorize the formula during problem solving and it makes things easy. If I want to find the distance formula then I just need to look at the formula I have written"
>
> (RI_F, Q9)

- **Emphasising the Goal**

The code indicated events where the students rewording what is asked in the problem. From the think-aloud transcripts, it was evident that the code was found in the majority of the students' problem solving. For example, Tara said,

> "What asked in the problem was Annisa.....Annisa's velocity".
>
> (TA_T, Problem 1, 5)

And in Problem 3, she said,

> "Then I need to find total *t* for using stair and *t* for using lift"
>
> (TA_T, Problem 3, 2)

Other students who demonstrated 'Emphasise the Goal' were Dayu, Fela, Reva and Nina.

- **Determining the Formula**

The code referred to behaviour where students deciding which formula to use. For example, Meri in Problem 1, said,

> "Find t_1 using linear motion formula...... v is s divide t. So t is equal to s divide v."
>
> (TA_M, Problem 1, 12)

Dayu demonstrated similar planning in Problem 2:

> " So I need to find it using formula .... the earlier formula but find the v. v_t is equal to v_o plus a times t."
>
> (TA_D, Problem 2, 15)

Majority of the students would undertake the 'Determining the Formula' because most of the problem required calculation. It could only be observed if they did it explicitly. It was interesting to find that some students were so used to associating Physics problems with equations or formula that even in some problems that did not need any calculations, they would perform 'Determining the Formula'. For example, Tara, after he had read Problem 1, said,

> "Bella's time ..... v is equal to s per t, then v is s per v. So Bella's time is 25 seconds. Oh.... it is already given in the problem."
>
> (TA_T, Problem 1, 13-16)

Noticing the tendency of the students to depend on formula, the researcher asked the students what was the first thing that came into their mind after they had read the problem, and the majority of them said the formula. Dayu said, "The formula, like oh ... this one distance so the formula for *s* is..... something like that come into my mind"

(RI_D, Q6)

All of the students who participated in this study demonstrated the tendency to use the formula to solve the problem. Fela also wrote all the one-dimensional kinematics formula before she started to solve the problem. The researcher asked the reason for her to do that, Fela insisted that a Physics problem is always linked to a formula.

- **Determining the Variable**

The code refers to behaviour where students decide the variable they must use in the equation, it usually happens in the middle of the calculation. The following think-aloud excerpt are some examples of the incidents,

"The *t* is ...... It means use the t_{final}"

(TA_D, Problem 2, 12)

"It means 4 is his initial velocity."

(TA_D, Problem 3, 11)

The incident also happened in Meri and Nina's problem solving,

"So it is moving. Then v_0 is not zero."

(TA_N, Problem 2, 12)

- **Formulating the Plan**

The code 'Formulating the plan' refers to behaviour where students generated a gradual plan on how to deal with the problem. It includes all process that coordinates the analysis information students made at the beginning then emphasise the goal of the problem, initiate the next steps they will take and how they conduct those steps in the best way to reach a solution. While carrying the plan, students have two different manners, some students carrying the plan in confidently and some students carrying the plan in an unsure manner (doing trial and error). The following think-aloud excerpt are some examples of the students' who formulated the plan certainly,

> "So I need to find s for both lorry and car ...."
>
> (TA_T, Problem 2, 4)
>
> "Then I need to find the velocity. ...."
>
> (TA_F, Problem 1, 2)
>
> "From here find the velocity of each runner first".
>
> (TA_M, Problem 1, 7)

Or Nina, where she clearly stated her whole plan to solve the problem,

> "First find velocity of Bella, Cindy and Dahlia then find § The time, sum to get Annisa's time. Then her velocity ...."
>
> (TA_N, Problem 1, 5)

There also incidents where students making a plan in an unsure manner and most of the time, the students would do trial-and-error to find out if the plan worked (trial-and-error). This kind of planning usually happened when the student encountered a problem that they perceive as difficult problems. For example, Tara in Problem 2,

> "Then distance of the car. Could I use the same formula? Um, I'll try to use the same formula ..... I don't know if it'll work."
>
> (TA_T, Problem 2, 9-10)

And also Dayu in Problem 3,

> "Formula uhm, s is equal to v_0 times t plus a half times a times t squared. Is this right? Let's just try it."
>
> (TA_D, Problem 3, 9)

It was very interesting to find that students resorted to 'trial-and-error' strategy when solving Physics problems. Students only used this approach when they faced (what they perceived as) difficult problems as they did not have enough experience and knowledge to solve the problem. They could only 'try'. It also shows what the students would do when they were stuck.

One common technique of 'trial-and-error' among the students was using a formula based on what the problem gave whether the formula is right or wrong, as Fela said in Problem 2, " I'll try it. I can change it later if it wrong ....". (TA_F, 11)

- **Breaking down the plan**

This code was concerned with any kind of brief planning between the first and the following calculations. It usually started with "so then..." or "and then..." to plan what to do next. The following excerpt of think-aloud illustrated the incident,

> " Cindy's, 100 was divided by 5 is equal to 20. Dahlia's 100 divided by 3 is equal to 33.33. **Then to get Annisa's** .... **add all their time**. 25 plus 20 plus 33.3. 78,3. **Then** 89.9 minus 78.3 ...."
>
> (TA_T, Problem 1, 17-22)

The code found in most students' problem solving process while they implemented their plan by making the computation.

- **Reflecting on the plan**

This code referred to behaviour where the students made judgement at her plan and trying another strategy if her previous strategy is not working. In other words, the students modified her previous plan. For example, Tara in Problem 2:

> "I don't think it is worked. I'll use another formula"
>
> (TA_T, Problem 2, 12-13)

And Nina in Problem 2,

> " The formula uhmm, is this? v_t squared is equal to v_o squared plus 2 times a times s. Wait... no no because there no distance, I'll use another formula"
>
> (TA_N, Problem 2, 8-9)

- **Relating the Concept**

This code referred to the students' efforts in finding or relating relevant concepts to a problem. There were a few concepts that the students could easily recognise from the problems even though they were not stated in the problems at all, such as 'linear motion' - including the variables involved like 'velocity, 'time' and 'distance'. The incident found in Dayu's, Fela's, Meri's and Nina's problem solving. Most of the students mentioned the relevant concept when they are deliberating the formula, as illustrated by excerpts from students' think-aloud transcript below,

> "*s* is .... non-uniform linear motion, so the formula ..."
>
> (TA_D, Problem 2, 5)

> "Then find *t*, using .... non-uniform linear motion formula."
>
> (TA_F, Problem 3, 7-8)

- **Deliberating the Formula**

The code refers to behaviour where students carefully thought a possible formula by matching the variables found in the problem. For example, Fela in Problem 2,

> "So there is 24 metres. First 10 seconds .... So this 10 seconds is for 40 metres. But for 24 metres. There is two *t*. Then find *t* using ....."
>
> (TA_F, Problem 2, 24-31)

Fela tried to think of a formula by analysing the variables given in Problem 3 statement. 'Deliberating the Formula' is related to 'Determining the Formula' where the former is the thinking process used to consider a formula by looking at the variables while the latter is the decision to solve the problem using a formula. It was not explicitly clear whether the students analysed the problems before 'Determining the Formula'. Not all of the behaviour in the transcripts that the researcher have coded 'Determining the Formula' would be preceded by 'Deliberating the Formula'. Most of the students showed 'Deliberating the Formula' explicitly before making 'Determining the Formula' but not consistently in all the problem solving process.

- **Deliberating the Variable**

'Deliberating the Variable' was coded when students verbalize their thought process when deliberate about variable to put in the equation during computation. This incident usually found before students 'Determining the Variable'. However, not all of this process was explicitly verbalised by students as it usually happen in students' mind. The following excerpts illustrate 'Deliberating the Variable',

> "*s* is 24. v_0 is ..... He is moving, right?"
>
> (TA_D, Problem 3, 10)

"It means 4 is his initial velocity."

(TA_D, Problem 3, 11)

Line 10 shows how Dayu deliberates the value of v_0, then line 11 shows she decides that the value was 4. Another example was found in the case of Fela,

"Wait ... The v_0 .... Not zero, right? I think it's 50. Because its v when it'll stop."

(TA_F, Problem 2, 10)

- **Assessing the plan**

When the student assesses her plan by analysing her current situation by looking at the situation in her work (e.g. look at variables she obtained from the problem and calculation) then decides her next step, it coded as 'Assessing the plan'. It usually found in the middle of computation. For example, the case of Tara in Problem 2, as illustrated by excerpts below,

"....There is no acceleration now. So I need to find *a*"

(TA_T, Problem 2, 5-6)

This incidents also found in Nina's problem solving,

"He already finishes 40 right? It's from first calculation"

(TA_N, Problem 3, 10).

- **Recognising Error**

'Recognising Error' was coded when the student realised that she made a mistake and tried to find or understand the mistake and how to make a correction. For a student to realise that she had made a mistake, it was usually through

‘Checking’ which will be explained in section 4.3.6. When a mistake was spotted, she would either make an immediate correction or undertake ‘Understand the Mistake’. Not all of the students could realise their own mistakes or make an effort to check. Those who did so and came to ‘Understand the Mistake’ usually would reach the correct answer.

When students realised a mistake had been made and did not know exactly where the mistake came from, the common method they employed was to search for the source of the mistake was by checking their calculation steps (‘Checking Calculation’, see section 4.3.6.). For example, Dayu in Problem 1, after realising her mistake, said:

> “Why the result is negative?”

(TA_D, Problem 1, 14)

She then went on to check her calculation and found that she made mistake in calculation.

> “Oh it should *t* minus t_{total} ... So 89.8 minus 78.3”.

(TA_D, Problem 1, 15-16)

This incident also found in Tara’s and Nina’s problem solving.

> “So *v* of Annisa, *v* equals to *s* per *t*. 100 divided 11.6 is 8.62. Wait.... I think I made a mistake, can I go back and fixed it? **Sure, go ahead**. Because they want to break the record at least 0.1, then the time should 89.8 ...”

(TA_T, Problem 1, 24-26)

- **Making Simple Calculation**

'Making Simple Calculation' is simply making a calculation or computation without involving another thinking process. It was found in all of students problem solving. Many examples fall within this code, as one-dimensional kinematics problem requires calculations to get the answer, one example is Tara in Problem 1,

> "Cindy's, 100 divided by 5 is equal to 20. Dahlia's, 100 divided by 3 is 33.3."
>
> (TA_T, Problem 1, 9-11)

- **Doing Algebra Calculation**

'Doing algebra Calculation' referred to an action where the student was doing mathematical algebra to arrange a formula into a format that facilitated problem-solving. For example, Tara in Problem 1,

> "*v* equals to s per *t*. The *t* is .... *t* is s per *v*."
>
> (TA_T, Problem 1, 13-14)

Another example,

> "v_t is equal to v_0 plus *a* times *t*. 50 is equal to 0 plus a times 20. a 50 divided by 20. So 2.5 m/s squared. Back to the first formula. *s* is equal to v_0 times *t* plus a half times *a* times *t* squared. v_0 is zero. So s is equal to *a* half times *a* times *t* squared."
>
> (TA_T, Problem 2, 7-8)

Majority of 'Doing Algebra Calculation' excerpts in the transcripts seemed like the students were only arranging the variables of a formula. However, after more data was analysed, the algebra performed by the students includes a part before the calculating process where they substituted the variables with appropriate numbers. ‘Doing Algebra Calculation’ was found consistently during students’ problem solving process because one-dimensional kinematics involves many algebra calculations.

- **Assessing the computation**

Assessing the computation is related to the conscious effort of students to check their work (computation) if the result is correct or if the goal had been achieved. During the problem solving process, students were found to assess their computation by two acts. First, students looked through the answer sheet to make sure that all the sub-goals were reached or to find a possible error in computation. It was usually at the end of the computation at which point the students were quite confident with their answer. The following excerpt from fieldnotes observation shows evidence that student did the ‘Assessing the Computation’ before stated the answer.

> Every time she finished calculation, she always looks back at her calculation.
>
> (FO_D, Problem 1, R4)

During the retrospective interview, to confirm what has observed, the researcher asked the participants, if they do the checking, all of them said yes. Most of them said they check their calculation before stated an answer. Dayu said,

> “I used to check my calculation, because one time I made mistake in calculation and it affects my score”
>
> (RI_D, Q12)

Another action students conduct to check their work is read the problem again at the end of the problem-solving process to check if their calculation is correct or the goal had been achieved. The incident found in the case of Nina for Problem 2, as illustrated in the following observation excerpt,

> After calculated the lorry's distance, she read the problem again.
>
> (FO_N, Problem 2, R3)

- **Reflecting on Oneself**

'Reflecting on Oneself' was coded when the students made a remark about themselves. In this study, it was only found in case of in Problem 3 Fela when she could not solve the problem she said," I think I have learnt this in math, but I don't remember" (TA_F, Problem 3, 12). And Reva, "I think I can't solve this problem fully" (TA_R, Problem 2, 6).

- **Speculating the Answer**

'Speculating the Answer' referred to behaviour when students making speculation about the solution of the problem by saying the possible answer. During the analysis, it was coded only in the case of Tara in Problem 2. After reading the problem she said,

> "So if the the car and lorry stopped before reach 500 m, no collusion, right?"
>
> (TA_T, Problem 2, 3).

Tara statement shows that she speculated about the problem answer.

- **Answering**

The code referred to an incident when the student arrived at an answer at the end of the problem-solving steps and gave the final answer of the problem, as illustrated in the following excerpt which was extracted from the think-aloud session,

“ So, to beat the record at least 0.1 seconds faster, Annisa should run at velocity 8.7 metres per seconds.”

(TA_D, Problem 1, 18)

“Then,....no collusion. Because *s* of the lorry added with *s* of the car is 325, less than 500”

(TA_T, Problem 2, 18)

“It means faster if he is using the star”.

(TA_M, Problem 3, 15).

The incident was coded in nearly every problem except those that the students who failed to solve the problem completely (e.g., Tara in Problem 3 and Reva in Problem 2).

The twenty-four behaviours discussed above were all the behaviour that students demonstrated during the problem solving process. Although it is important to note that there are no students who demonstrated all twenty-four behaviours while solving one problem. Thus, it is important to note that some of the behaviours above may only found in one problem solving case.

4.3 Metacognitive Behaviour that Students Exhibit while Solving One-dimensional Kinematics Problems

After coding all of students behaviour while solving one-dimensional kinematics problems, the metacognitive behaviours were identified and classified into phases based on the metacognitive framework from Yimer & Ellerton (2010). Thus, this section presents the metacognitive behaviour that students exhibit while solving one-dimensional kinematics problem to answer the first research question of this study. Table 4.3 summarises the metacognitive behaviour that students exhibit while solving one-dimensional kinematics problem.

Table 4.3

Metacognitive Behaviour that Students Exhibit while Solving One-dimensional Kinematics Problems

Phase	Metacognitive Behaviour
Engagement	Rereading Reading with strategy Arrange information Draw a sketch Making sense of the problem Relating the concept
Transformation-Formulation	Speculating the answer Formulating a plan
Implementation	Breaking down the plan Assessing the plan Reflecting on the plan
Evaluation	Assessing the computation

4.3.1 Engagement

In the engagement phase, problem solver's metacognitive behaviour involves initial encounter and analysing the information in the problem. The problem solver exhibit the behaviour that aims to understand the problem at the beginning of the problem solving process. During the analysis process, six metacognitive behaviours were classified in this phase: rereading, reading with strategy, arrange information, draw a sketch, making sense of the problem and relating the concept.

4.3.1.1 Rereading

Reading is originally categorised as a cognitive behaviour that characterises initial engagement of the problem solver. But as the problem solver decides to reread the problem, she may have a different purpose from the original like what was confirmed during the retrospective interview:

Q22: Why did you reread the problem?
All the problem is long, so I need to read it twice to understand it.

((RI_T, Problem 2)

Q10: After arranged the information, you look back to the problem, do you read it again?
Yes, I try to understand the situation of the problem

(RI_M, Problem 1)

Thus, rereading was classified as metacognitive behaviour. Because it served as a catalyst for understanding the problem.

4.3.1.2 Reading with strategy

'Reading with strategy' refers to student's behaviour where she read the problem statement in a way to ensure a better understanding of a problem. The behaviour was found in all of the participant's problem solving. As explained in section 4.3.3, several reading strategies are employed by students in this study. First, they could read the problem for the first time as a text and then read it one more time as found in Tara, Dayu and Nina's problem solving.

Then Nina read back the problem ....

(FO_N, Problem 2, R2)

After writing the information, she read the problem again ....

(FO_T, Problem 1, R2)

During the retrospective interview, Nina and Tara acknowledge that they read the problem statement more than once. Tara said,

> "Yes, I read it again. The problem is long, so I want to make sure I've not missed anything important."
>
> (RI_T, Q10)

Second, the student read the problem and making their own representations of the problems using different words, symbols or illustration. As found in Reva's problem solving,

> She also draws a sketch to illustrate the problem situation
>
> (FO_R, Problem 2, R2)

Third, they read while arranged the information. This was evident in all of the students and was seen as a strategy frequently used by them. One example is Dayu as illustrated in fieldnotes observation excerpt below,

> Dayu read the problem while jotted down the information ....
>
> (FO_T, Problem 1, R1)

Last, the student could read the problem and executing the calculation of the first goal at once even before finish reading the problem. This was coded in the case of Fela in Problem 1 and 3 and Dayu in Problem 3, as illustrated in the following fieldnotes observation transcript, Fela read the problem, write down a few information and immediately plan and calculate the first sub-goal.

(FO_F, Problem 1, R1)

During the retrospective interview, when she was asked about her action, she acknowledged doing so and gave the reason behind her action, she said,

"It was easier for me, I usually do that in exam to save the time"

(RI_F, Q6)

'Reading with strategy' was classified as metacognitive behaviour because it showed that student regulates their behaviour of 'reading' in a way that allows them to understand the problem.

4.3.1.3 Arrange the Information

This code referred to incidents where the students jotted down the information from the problem. This was evident in all of the students and was seen as a strategy frequently used by them. During the analysis, it was found that there were two different ways to keep track of the information. Most the students preferred to write the information down (e.g., Tara, Dayu, Fela, Meri, and Nina) and the other underlined the information in the problem sheet (e.g., Reva) (describe in section 4.3.1.4). There were several reasons behind the action. First, it was to help them to remember the important information and to lessen the burden on their short-term memories. Fela said,

"If the problem is long, I always do it so it can be a guideline for me during solving the problem. And the most important is I don't have to look back at the problem repeatedly."

(RI_F, Q8)

Second, it was to help them to focus on the relevant information and determine the formula to use. Tara and Meri have the same opinion about the reason behind their action.

> "It made my task easier, I could see which unit was already given and which was not. From that, I can determine which formula I should use."
>
> (RI_T, Q13)

> "It is easier for me, determine what already given in the problem and what are not there."
>
> (RI_M, Q27)

Third, it was a habit. Most of the students agreed that arranging information is their habit during problem solving process. For Dayu, she said,

> "Absolutely, since the first time I learn Physics my teacher teach me to write the information first before solve the problem. Now, during exam usually my lecturer said that if we made the arranged information, he will give us bonus score".
>
> (RI_D, Q24)

As for Reva's reason to underlined the key information when she read the problems at the first time is simply to save time.

4.3.1.4 Draw a Sketch

'Draw a sketch' was coded when students drawing to illustrate the situation in the problem. During the analysis, the incident was coded in case of Reva and Nina in Problem 2.

.... while attempt to draw an illustration of the situation in the problem.

(FO_N, Problem 2, R2)

She also draws a sketch to illustrate the problem situation while reading.

(FO_R, Problem 2, R2)

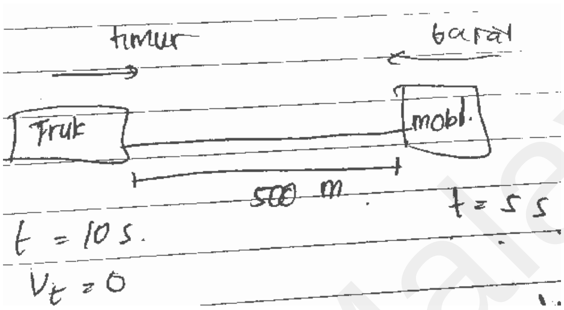


Figure 4.2 Reva's Sketch in Problem 2

Reva drew an illustration by labelling the objects and values. While Nina did not systematically use the illustration to help him in organising the information. It was only two arrows without any label.

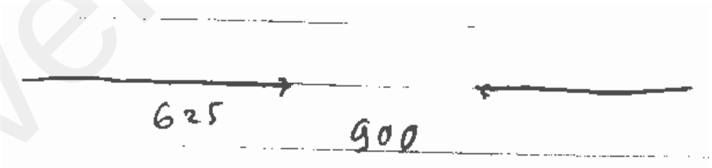


Figure 4.3 Nina's Sketch in Problem 2

The researcher asked both of them during the retrospective interview for their reasons for drawing an illustration. Both of them gave a similar reason which as the illustration help them to understand the problem. Nina particularly said,

> "It's easier to understand the concepts if I make an illustration. In my opinion, it is impossible to imagine what happened in the problem if we don't sketch it"

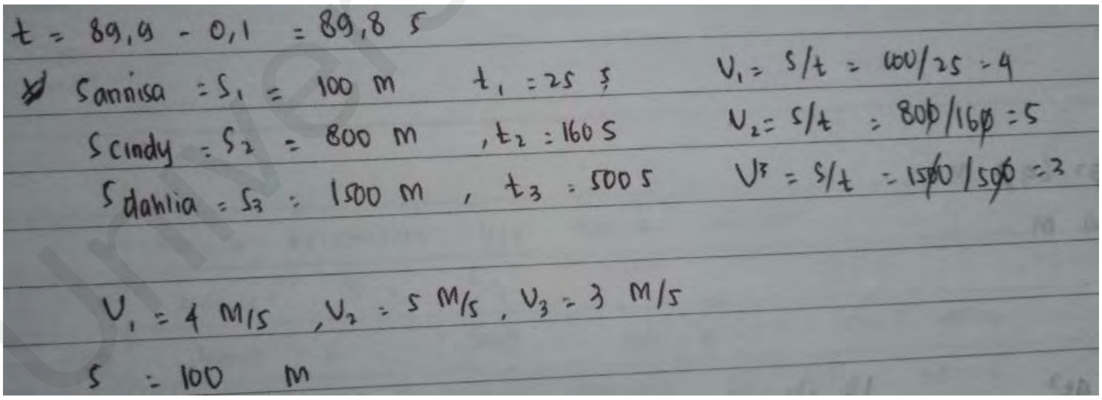
(RI_N, Q17)

4.3.1.5 Making Sense of the Problem

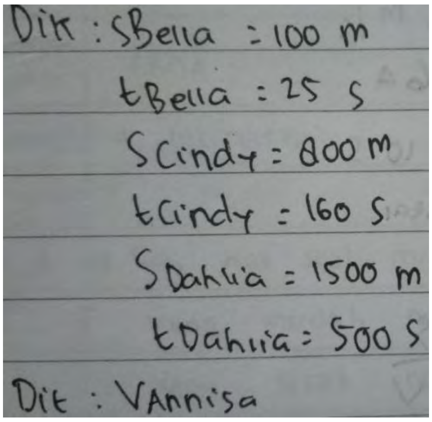
Making sense of the problem is behaviour where a student tried to understand the problems situation by rewording the problem statement or presenting them in different ways, words, or symbols. This action showed that the students' effort to understand the problems. It was found in all of the students' problem solving as described in section 4.3.5. For example, Meri in solving Problem 1, read the problem then simplified it into her own words, saying:

> "There is distance, they join relay. It says 0.1 faster than 89.9."
>
> (TA_M, Problem 1, 2)

Meri's behaviour shows how she rewording the problem in her own words to show her understanding of the problem. Another behaviour was presenting the information given in the problem into physics symbol. It was shown in the students' answer sheet



(AS_M, Problem 1)



(AS_N, Problem 1)

4.3.1.6 Relating the Concept

Second, the students relating relevant concepts to a problem. The incident found in Dayu's, Fela's, Meri's and Nina's problem solving, as illustrated by excerpts from students' think-aloud transcript below,

"*s* is .... non-uniform linear motion, so the formula ..."

(TA_D, Problem 2, 5)

"Then find t, using .... non-uniform linear motion formula."

(TA_F, Problem 3, 8)

By identify the relating concept, students able to determine the formula they should use to solve the problem.

4.3.2 Transformation-formulation

Transformation-formulation is a phase where students transform their understanding to build a plan and take the action. In this study, only two metacognitive were identified that belong to this phase, they are speculating the answer and formulating the plan.

4.3.2.1 Speculating the Answer

'Speculating the answer' is a behaviour where students make speculation about the solution for the problem based on their analysis of the problem. In this study, only one behaviour include as 'Conjecturing', it is 'speculating the answer'. During the analysis, it was coded only in the case of Tara in Problem 2. After reading the problem she said,

> "So if the car and lorry stopped before reaching 500 m, no collusion, right?"
>
> (TA_T, Problem 2, 3).

4.3.2.2 Formulating the Plan

'Formulating the Plan' refers to action where students generated a gradual plan on how to deal with the problem. It includes all processess that coordinates the behaviour of analysing information from the problem that students made at the beginning then emphasising the goal of the problem, initiate the next steps they will take and how they conduct those steps in the best way to reach a solution. Therefore, if students just do one act of planning such as only stated what they would do, it will not be coded as 'formulating the plan'. 'Formulating the plan' was found in the case of Tara, Dayu, Nina, and Fela.

2.	Uhmm ... So, they are opposite to each other. Lorry go to the east while car go to the west. they stepped on the brake immediately. The lorry took 10.0 seconds to stop while the car took 5.0 seconds to stop. Will there be any road accident happening? Why?	Reaing with strategy (rewording) then rereading the problem
3.	So if the the car and lorry stopped before reach 500 m, no collusion, right?	Speculating the answer
4.	So I need to find s for both. Formula for distance. s is equal to v_0 times t plus a $half$ times a times t square	Formulate the plan
5.	There is no accelaration now. So I need to find a first.	Assessing the plan by looking at her current situation
6.	I will use this formula. v_t is equal to v_0 plus a times t	Determining the formula
7.	. 50 is equal to 0 plus a times 20. a 50 divided by 20. So 2.5 m/s squared	Doing algebra calculation
8.	Back to the first formula. s is equal to v_0 times t plus a half times a times t squared. v_0 is zero. So s is equal to a half times a times t squared. s is equal to a $half$ times 2.5 times §. t § Oh 10 second because time to stop. So the distance is 125. That's for truk	Breaking down the plan then doing algebra calculation
9.	Then distance for car. Could I use the same formula? §. Um §	Deliberating the formula
10.	I'll try to use the same formula ..... I don't know if it'll work."	Plan unsurely (trial-error)
11.	s is equal to v_0 times t plus a half times a times t squared §.	Doing algebra calculation
12.	I think it doesn't work.	Assessing the plan
13.	I'll use another formula	Reflecting on the plan by modify previous plan
14.	v_t squared is equal to v_0 squared plus 2 times a times s but no v_t for car. Find v_t §	Determining formula then breaking down the plan again
15.	v_t is equal to v_o plus a times t. v_o is zero. So v_t is 4 times 10. v_t is 40.	Doing algebra calculation
16.	Back to formula for distance.	Breaking down the plan
17.	v_t squared is equal to v_0 squared plus 2 times a times s. 40 square is equal to zero plus 2 times 4 times s. 1600 is equal to 8 times s. s is 1600 divided by 8. So s for car is 200 m.	Doing algebra calculation
18.	Then § No collusion. Because s lorry added with s truk is	Answering

The segment above is Tara's think-aloud transcript Problem 2. It shows how Tara gradually plan her problem solving, start from rereading the problem to understand the problem, then speculate about the possible answer, then formulate her plan to get the answer. Her plan also going when she assessing her plan by looking at her situation before carrying her next plan by executing the computation. The transcript also show how she also breaking down the plan, carrying out plan unsurely, and reflecting on her plan then modifying her previous plan by trying another formula.

4.3.3 Implementation

The implementation phase is a phase where student executed their plan while also exploring and monitoring the plan. Three identified metacognitive behaviour in this study belong to this phase.

4.3.3.1 Breaking down the Plan

'Breaking down the plan' refers to behaviour where student making any kind of brief planning between the first and the following calculations. It means students deal with sub-goal of the problem one by one. The following excerpt illustrates how student break the plan into sub-plan,

7.	But it's § But find the *a* first, *a* §
8.	The formula uhmm § Is this? v_t squared is equal to v_o squared plus 2 times *a* times *s*.
9.	Wait no no. Because there is no distance. I'll use another formula. so this? v_t is equal to v_o plus *a* times *t*.
10.	*a* times 20. 50 equals to 20*a*. *a* is 50 divided by 20. 2.5
11.	Then ... continue to the earlier calculation
12.	v_0 is zero. But § Here the lorry is going to stop right?
13.	So it is moving. Then v_0 is not zero. It's § Oh here 50
14.	Then 50 times 10. Plus 100 times 2.5 ... So 500 plus 125. Equals to 625. So the distance of lorry is 625. It ... to the East 625.
15.	Car was moving .... acceleration ... to the West. Opposite to the lorry. The distance between them is 900. So find the distance of car
16.	Formula umm § I think it's same
17.	So v_0 is § none. Then find it first
18.	Find it using formula § I think this

(TA_N, Problem 2, 7-18)

The excerpt above is from Nina's think-aloud transcript for Problem 2. The excerpt shows how Nina carrying plan by deal with sub-plan one by one. First, Nina finds the *a* then she back to calculate the *s*, after that she continues to calculate the distance of car but before that she needs to find v_t. This behaviour also found in case of Dayu, Tara, and Fela.

4.3.3.2 Assessing the Plan

'Assessing the plan' refers to behaviour where the student assesses her plan by analysing her current situation by looking at the variables she obtained from the problem and calculation. The following excerpt illustrates the assessing plan behaviour,

4.	First § Here I need to find both 's' of lorry and car.
5.	s_{lorry} § s is equal to v_0 times t plus a half times a times t squared § But there is no a. It means I need to find a?
6.	Find a with § Try use this v_t is equal to v_o plus a times t
7.	v_t is § 50. Zero plus a times t. t is 20. a equals to 50 divided by 20. a is 2.5
8.	Now calculate the s
9.	s is § s is equal to v_0 times t plus a half times a times t squared. v_0 is zero, t is § Means zero times t is equals to zero.
10.	Wait § The v_0 § Not zero, right? I think it's 50. Because v when it'll stop.
11.	I try it, I can change it later if it wrong. 50 times t to stop. 50 times 10 Plus a half. a is 25 times 10. 10 times 10 is 100. 100 divided by 2 is 50. 50 times 2.5. 125. 500 plus 125. Is 625 metre.
12.	Now car § t check. a check. There is no v_t.
13.	So find v_t first §

(TA_F, Problem 2, 4-13)

The excerpt was from Fela's think-aloud transcript in problem 2. First, Fela said she to find the distance of lorry and car. Then she realised, she needs variable a which was not found in the problem. So she deals with that first, after that she calculated the distance and deliberating the v_0 value because it was not explicitly given in the problem. It shows how Fela assess her plan by examining what already given in the problem and what she needs to find first before start the computation. The behaviour also found in the case of Tara and Nina.

4.3.3.3 Reflecting on the Plan

'Reflecting on the plan' refer to behaviour where a student made a judgement at her plan and made a modification to the previous plan if needed. In other words, students reflect on the appropriateness of plan (formula or analysis) and whether performing the plan will ensure the result will be obtained. The outcome of this behaviour is either to modify or to abandon a plan. During the analysis, the behaviour found in Tara's and Nina's problem solving.

"I don't think it is worked. I'll use another formula"

9.	Then distance for car. Could I use the same formula? §. Um §	Deliberating the formula
10.	I'll try to use the same formula ..... I don't know if it'll work."	Plan unsurely (trial-error)
11.	s is equal to v_0 times t plus a half times a times t squared §.	Doing algebra calculation
12.	I think it doesn't work.	Assessing the plan
13.	I'll use another formula	Reflecting on the plan by modify previous plan
14.	v_t squared is equal to v_0 squared plus *2* times a times s but no v_t for car. Find v_t §	Determining formula then breaking down the plan again
15.	v_t is equal to v_o plus a times t. v_o is zero. So v_t is 4 times 10. v_t is 40.	Doing algebra calculation

(TA_T, Problem 2, 12-13)

And Nina in Problem 2,

" The formula uhmm, is this? v_t squared is equal to v_o squared plus 2 times a times s. Wait... no no it is not working because there no distance, I'll use another formula"

6.	But it's § But find the a first, a §	Breaking down the plan
7.	The formula uhmm § Is this? v_t squared is equal to v_o squared plus 2 times a times s.	Deliberating and Determining the formula
8.	Wait no no. It is not working. Because there is no distance. I'll use another formula. so this? v_t is equal to v_o plus a times t.	Reflecting on the plan and modify her plan
9.	a times 20. 50 equals to 20a. a is 50 divided by 20. 2.5	Doing algebra calculation

(TA_N, Problem 2, 8)

4.3.4 Evaluation

Evaluation is a phase where problem solver made judgment towards her action, her plan and her solution during the problem solving process. In this study, only one identified metacognitive behaviour belong to this phase: assessing the computation.

4.3.4.1 Assessing the Computation

'Assessing the computation' refers to behaviour where students made an effort to check their work consciously by look back at or read the problem again after finish the calculation. There two strategy students employed while assessing their computation: looking back and reading back. The following excerpt from Dayu's fieldnotes observation shows evidence how student assesses her computation before stated the answer.

She looks back at her calculation before stating the answer.

(FO_D, Problem 5, R5)

After confirming the behaviour during the retrospective interview, Dayu acknowledged that she looked back to check her calculation (RI_D, Q11).

Assessing the computation by reading back was only found in the case of Nina,

9.	a times 20. 50 equals to $20a$. a is 50 divided by 20. 2.5	Doing algebra calculation
10.	Then ... continue to the earlier calculation	Breaking down the plan
11.	v_0 is zero. But § Here the lorry is going to stop right?	Deliberating the variable
12.	So it is moving. Then v_0 is not zero. It's § Oh here 50	Determining the variable
13.	Then 50 times 10. Plus 100 times 2.5 ... So 500 plus 125. Equals to 625. So the distance of lorry is 625. It ... to the East 625.	Doing algebra calculation
14.	Car was moving .... acceleration ... to the West. Opposite to the lorry. The distance between them is 900. So find the distance of car	Assessing the computation by reading the problem again
15.	Formula umm § I think it's same	Deliberating and determining the formula
16.	So v_0 is § none. Then find it first	Breaking down the plan
17.	Find it using formula § I think this	Deliberating and determining the formula
18.	v_t is equal to v_o plus a times t. v_t is the one I need to find. v_o is zero because it moving from starting point. Plus 4 times 10. v_t is 40	Doing algebra calculation
19.	Then §	Breaking down the plan
20.	40 times t for car to stop. 5 plus a half of 4. 4 times t is 5. The square of 5. 200 plus 25 times 4. So 250.	Doing algebra calculation
21.	Then no accident happen. Because it is less than 900	Answering

(TA_N, Problem 2)

Assessing the computation allow students to recognise if something wrong during calculation and fixed it. Because the awareness was an outcome from doing the checking. It was found during Tara's, and Nina's problem solving.

> "If I sum their time, 33.3 plus 20 plus 25. 78.3 seconds. Must beat 89.9. So 89.9 minus 78.3. Uhm.... Wait, I forget something. First, 89.9 minus 0.1 In order to beat the record"

(TA_N, Problem 1, 14-16)

During the retrospective interview, Nina said that she realises that she forgot to subtract because she looks back at her calculation

Q11: During the calculation you realise that you forget that you need to substract the time with 0.1. How did you realise it?
I look back and realise I did not substract the time yet.

(RI_N, Q11)

Data analysis shows that every student exhibited a different pattern of metacognitive behaviour while solving one-dimensional kinematics problem. There is a student who exhibited eleven metacognitive behaviours while solving Problem 2 while the other students only exhibited four metacognitive behaviour while solving the same problem. Even the same student was found exhibited different pattern of metacognitive behaviour across different problems. For example, Nina demonstrated eight metacognitive behaviour while solving Problem 1, but while solving Problem 2, she demonstrated eleven metacognitive behaviours. A student may have shown evidence of metacognitive behaviour as she plans, analyzes, and makes thoughtful decisions while solving one problem, however, the same student was then seen having the difficult time during solving the problem. The students were not consistent in the metacognitive behaviours they exhibited across problems.

'Rereading, 'Reading with strategy', 'Arrange the information', 'draw a sketch', 'Making sense of the problem', 'Relating the concept', 'Speculating the answer', 'Formulating the Plan', 'Breaking down the plan', 'Assessing the plan', 'Reflecting on the plan', and 'Assessing the computation' were metacognitive behaviour that identified in this study. However, those behaviours did not exactly exhibit by all of the students but it represents the students' metacognitive behaviour while solving one-dimensional kinematics problems. 'Speculating the answer' for example were only exhibited by one student during problem solving process. In fact, no one was found to exhibit all of the behaviours during a single problem-solving process.

4.4 Role of Metacognition in Problem Solving Process of One-dimensional Kinematics

After identifying the metacognitive behaviours, the next step is examining how these behaviours contributed to student problem solving. The analysis process was done by examining the uses of metacognitive behaviours during problem solving process and how these behaviours help students to complete their problem solving. It was evident that students' metacognitive behaviours influenced their problem solving process. Table 4.4 shows the role of metacognitive behaviours in problem solving process of one-dimensional kinematics found in this study.

Table 4.4

Role of Metacognition in Problem Solving Process of One-dimensional Kinematics

Metacognitive Behaviour	Role in Problem Solving Process
Rereading Reading with strategy Arrange the information Draw a sketch Making sense of the problem Relating the concept	Construct understanding of the problem
Formulating the plan Breaking down the plan Reflecting on the plan	Regulate the action during problem solving
Assessing the plan Assessing the computation	Monitor the progress during problem solving

Metacognition enables the student to construct their understanding of the problem. Metacognitive behaviours that ascertain this role related is rereading, reading with strategy, arrange information, draw a sketch, making sense of the problem, and relating the concept. These metacognitive behaviours aim to get the initial understanding and analyse the information given in the problem. The six behaviours were found consistently exhibited by the majority of students at the beginning of the problem solving process. Based on the retrospective interview transcript, students aware that they exhibited this behaviour and give the reason behind their behaviour which are showed by the following interview excerpt,

Tara answer while she was asked why she read the problem more than once,

> "All the problem is long, so I need to read it twice to understand it."
>
> (RI_T, Q22)

Meri answer while she was asked why she arranges information,

> "It is easier for me, determine what already given in the problem and what are not there."
>
> (RI_M, Q27)

Meri's reason why she made a sketch of problem,

> "It makes the situation real for me and help me understand the problem better"
>
> (RI_R, Q13)

And Nina's reason for why she read in silent and why she draws a sketch,

> "Yes, for me it is easy to understand if I read it silently"
>
> (RI_N, Q7)
>
> "It's easier to understand the concepts if I make an illustration. In my opinion, We can't imagine the problem if we don't draw it."
>
> (RI_N, Q17)

The excerpts show that the reason behind students' behaviour related to understanding the problem. These metacognitive behaviours help students grasp an understanding of the problem, what the problem about, what the problem asked, and what the parameter the problem already gives. Students need to understand all of the information to solve the problem. It was also found that students who spent more time reading and analyse the information given in the problem develop meaningful understanding toward the problem and at the end solve the problem successfully.

By understanding the problem, students can initiate the plan, the analysis shows that students who spent more time in initial understanding and analysing the information, exhibited clear planning step rather than students who spent less time in understanding the problem. For example, the figures below show segments of think-aloud transcript of two students for the same problem,

1.	A lorry moved to the East from stationary. Means the lorry's v_0 is zero. v_t is 50 m/s. t is 20 seconds. While a car was moving with an acceleration. a is equal to 4 m/s squared. To the West. This ... to the East. In 10 seconds from starting point. Car moved. The distance between loory and ...	Reading with strategy (Read the problem while write the informationa and draw sketch)
2.	A lorry moved to the East	Reresading
3.	So I need to find the distance	Emphasising the goal
4.	s_{lorry} is v times t	Determining formula
5.	Wait this is NLM (re: NLM is Non-uniform Linear Motion). So § s is equal to v_0 times t plus a half times a times t squared	Relating the concept
6.	But it's § But find the a first, a §	Breaking down the plan
7.	The formula uhmm § Is this? v_t squared is equal to v_o squared plus 2 times a times s.	Deliberating and Determining the formula
8.	Wait no no. It is not working. Because there is no distance. I'll use another formula. so this? v_t is equal to v_o plus a times t.	Reflecting on the plan and modify her plan
9.	a times 20. 50 equals to 20a. a is 50 divided by 20. 2.5	Doing algebra calculation
10.	Then ... continue to the earlier calculation	Breaking down the plan
11.	v_0 is zero. But § Here the lorry is going to stop right?	Deliberating the variable
12.	So it is moving. Then v_0 is not zero. It's § Oh here 50	Determining the variable

(TA_N, Problem 2)

1.	A lorry moved to the East from stationary until it reached a constant speed of 50 m/s. Given v_{lorry} is 50 m/s. Then the time is 20 seconds. While a car ... v_{car} is not known. a_{car} is 4 m/s squared. The time of car is 10 seconds. The car moved into the lorry's lane in order to ... When both the lorry and the car were ... The total distance is 800 metre. Lorry need 10	Reading with strategy (Reading while write information)
2.	The question, will there be any accident?	Emphasising the goal
3.	So v_{lorry} is 50 m/s then v_{car} is v_t is equal to v_o plus a times. v_o is § Because it's not moving then zero. Zero plus 4 times 10. v_{car} is 40 m/s.	Doing algebra Calculation

(TA_M, Problem 2)

If we compare the two figure, it is apparent that Nina's spent more time to understand the problem by rereading, draw a sketch, write and arranging information, relating concept before she stated her plan by determining what she would do and what formula she should use in computation. While Meri read the problem then arrange information and stating the goal of the problem before immediately execute the computation. The planning step is not clear in Meri's and it confirmed by her answer during the retrospective interview, she said she did not plan before calculate (RI_M, Q11).

It was also evident that the majority of behaviours that aim to get initial understanding and analysing information occurred before 'Planning' during problem solving. The retrospective interview also indicated that these behaviour lead the students to formulate a plan.

> "It made my task easy, I can see which unit is already stated or not. From that, I can determine which formula I should use."
>
> (RI_T, Q13)

The excerpt above is Tara's answer when she was asked why she listing the information. She said from the listing information, she can determine the formula which shows that analysing the information lead to plan what formula to use.

Metacognition enables student to regulate their action during problem solving. This role was related to 'Formulating the plan' 'Breaking down the plan' and 'Reflecting on the plan' behaviour. Formulating the plan is a gradual process that coordinates the analysis information students made at the beginning then emphasise the goal of the problem, initiate the next steps they will take and how they conduct those steps in the best way to reach a solution. Breaking down the plan refer to behaviour where students carrying out the plan by breaking down the plan into manageable sub-plan. While reflecting on the plan refer to behaviour where students reflect on the appropriateness of plan and whether performing the plan will ensure the result will be obtained. These behaviours enable students to regulate their action and decision during problem solving. For example,

2.	Uhmm ... So, they are opposite to each other. Lorry go to the east while car go to the west. they stepped on the brake immediately. The lorry took 10.0 seconds to stop while the car took 5.0 seconds to stop. Will there be any road accident happening? Why?	Reaing with strategy (rewording) then rereading the problem
3.	So if the the car and lorry stopped before reach 500 m, no collusion, right?	Speculating the answer
4.	So I need to find s for both. Formula for distance. s is equal to v_0 times t plus a $half$ times a times t square	Formulate the plan
5.	There is no accelaration now. So I need to find a first.	Assessing the plan by looking at her current situation
6.	I will use this formula. v_t is equal to v_0 plus a times t	Determining the formula
7.	. 50 is equal to 0 plus a times 20. a 50 divided by 20. So 2.5 m/s squared	Doing algebra calculation
8.	Back to the first formula. s is equal to v_0 times t plus a half times a times t squared. v_0 is zero. So s is equal to a half times a times t squared. s is equal to a $half$ times 2.5 times §. t § Oh 10 second because time to stop. So the distance is 125. That's for truk	Breaking down the plan then doing algebra calculation
9.	Then distance for car. Could I use the same formula? §. Um §	Deliberating the formula
10.	I'll try to use the same formula ..... I don't know if it'll work."	Plan unsurely (trial-error)
11.	s is equal to v_0 times t plus a half times a times t squared §.	Doing algebra calculation
12.	I think it doesn't work.	Assessing the plan
13.	I'll use another formula	Reflecting on the plan by modify previous plan
14.	v_t squared is equal to v_0 squared plus *2* times a times s but no v_t for car. Find v_t §	Determining formula then breaking down the plan again
15.	v_t is equal to v_o plus a times t. v_o is zero. So v_t is 4 times 10. v_t is 40.	Doing algebra calculation
16.	Back to formula for distance.	Breaking down the plan
17.	v_t squared is equal to v_0 squared plus *2* times a times s. 40 square is equal to zero plus 2 times 4 times s. 1600 is equal to 8 times s. s is 1600 divided by 8. So s for car is 200 m.	Doing algebra calculation
18.	Then § No collusion. Because s lorry added with s truk is	Answering

(TA_T, Problem 2)

The segment of think-aloud transcript above shows how student able to regulate their action by carrying out the plan she made and implemented by breaking down the plan into sub-goal throughout her problem solving process (4-10). The students also able to regulate their decision by reflecting on the problem (12-13). Tara immediately decided to abandon the previous formula and try another formula, when she realised that the formula was wrong. The analysis also shows that students who exhibited the ‘formulate the plan’ behaviour, think before they act. It is evident from their think-aloud transcripts which were coded as ‘deliberating .....’ act, such as deliberating the formula.

It is evident that students who have done formulating the plan, breaking down the plan and reflecting on the plan able to fix or adjust their way to solve the problem by changing formula or doing trial and error by carrying plan unsurely. This happened in the case of Dayu, Nina, Tara. Their transcripts also showed that they involved in more analysis action during computation than the other students.

Metacognition enables student to monitor their progress during problem solving. ‘Assessing the plan’ and ‘Assessing the computation’ were related to this role. Once a plan is implemented, students require to keep track and evaluate their plan and the implementation which was the computation. Therefore, they need to assess their plan and their computation. The segments of think-aloud of two students below compare of students who assess her plan and computation and the others who did not.

2.	What I need to find is Annisa's velovity, right?	Emphasising the goal
3.	Then it means uhm §	
4.	First find velocity of Bella, Cindy and Dahlia then find § The time, sum in order to get Annisa's time, Then her velocity	Formulating the plan
5.	*v* uhm	Deliberating formula
6.	*v* is *s*/*t*	Determining formula
7.	100 divided by 25 is 4. 4 m/s. Then Cindy, 800 divided by 160. 5, 5 m/s. v_{Dahlia} 1500 divided by 1500. 3 m/s	Doing algebra calculation
8.	Then § After *v* is done, § Find *t* for 100 metre right?	Breaking down the plan
9.	Then if the track is 100 metre. *v* is *s*/*t*. Find the *s*. *t* is *s*/*v*	Deliberating and Determining formula
10.	The velocity is 4. So 25 seconds. *t* is *s*/*v*. 100 divided by 5, Equals to 20. *t* is *s*/*v*. 100 divided by 3. Equals to § 33.3 seconds	Doing algebra calculation
11.	Then § Sum all	Breaking down the plan
12.	If I sum their time, 33.3 plus 20 plus 25. 78.3 seconds. Must beat 89.9. So 89.9 minus 78.3. Uhm §	Making simple calculation
13.	Wait, I forget something. First, 89.9 minus 0.1 In order to beat the record	Recognising error
14.	89.8 minus 78.3. Equals to 11.5. It means time of Annisa must be 11.5 seconds	Making simple calculation
15.	Now, find the velocity	Breaking down the plan
16.	Annisa's velocity equals to § *s*/*t*. Equals to, the track is 100. *t* is 11.5. 100 divided by 11.5.	Doing algebra calculation
17.	So 8.7 m/s is Annisa's velocity	Answering

(TA_N, Problem 1)

1.	Bella, Cindy, Dahlia and Annisa will join 100 m x 4 (each runs 100 m) relay. Bella can finish a 100 m race in 25 s, Cindy can finish a 800 m race in 160 s and Chris can finish a 1500 m race in 500 s. The record of the 100 m x 4 relay in school is 89.9 s. Bella is the first runner of the team, followed by Cindy and Dahlia. If they all run at their usual speed as above, Annisa as the last runner, how fast should Annisa run, at least to beat 0.1 s of the record (0.1 s faster than the record)?	Reading
2.	There is a distance, they join the relay. It says 0.1 faster than 89.9. It means *t* is 89.9 Then minus 0.1. So it is 89.8 seconds	Reading with strategy *(strategy: rewording)*
3.		
4.	Then here the velocity of each runner is unknown.	Reading with strategy *(strategy: rewording)*
5.	The question is *v* Annisa	Emphasising the goal
6.	Let say this s_1. s_1 is 100 metre. t_1 is 25 seconds. Then s_2 is § s_2 is 800 metre. Then t_2 is 160 seconds. s_{Dahlia} is s_3 1500 metre. t_3 is 500 seconds	Arrange the information
7.	From here find the velocity of each runner first	Formulate plan
8.	*v* is *s* per *t*. Then 100 divided by 25 is 4. *v* is *s* per *t*. 800 divided by 160. 5. The third is v_{Dahlia}.. *s* divided by *t*. 1500 divided by 500 is 3	Doing algebra calculation
9.	Okay, here found that v_1 is 4 m/s. v_2 is 5 m/s. And v_3 is 3 m/s.	
10.	Then § calculate the time	Breaking down the plan
11.	So the distance for each runner is 100 metre	Determining the variable
12.	Then *t* is § Find t_1 with linear motion formula. *v* is *s* per *t*. So *t* is *s* per *v*.	Deliberating and Determining the Formula
13.	t_1. So s_1 § oh right 100. Divided by 4. Equals to 25. t_2 is 100 divided by 5 so it's 20 seconds. t_3 is 100 divided by 3. 33.3 seconds	Doing algebra calculation
14.	Then find *t* for Annisa. Sum all of this then minus 89.9	Breaking down the plan
15.	Then t_{Annisa} is t_{total} minus ... 25 plus 20 plus 33.3. Equals to 78.3. So § 89.9 minus 78.3. 11.6 seconds	Making simple calculation
16.	So v_{Annisa} is *s*/*t*. 100 divided by 11.6. 8.6	
17.	So Annisa's velocity is 8.6	Answering

(TA_M, Problem 1)

Nina and Meri are solving the same problem. In the first segment, it shows when Nina made the mistake, she realised it and immediately fixed it (line 15-16). While Meri in the second segment, she also made the same mistake with Nina which was forgotten to do subtraction in the computation. However, she did not notice the mistake, although she already highlighted this important information after reading the problem (line 3). Observation field notes showed that Nina look back after her computation and Meri did claim that she check her answer during her retrospective interview, but it possible she did not assess her plan. From data collected, it was clear that Meri possessed the necessary knowledge to solve the problem, but she overlooked the important information she already highlighted after she read the problem. While Nina also almost made the same mistake, but she looked back on her work and that enables her to realise her mistake. Thus, it showed that students who assessing her plan and computation were able to monitor and evaluate their progress during problem solving. This incident also happened in Tara's and Dayu's problem solving, when they immediately realised their mistake after look back at their work.

4.5 Summary

The objectives of this research are to find out the metacognitive behaviour exhibited by the students while solving one-dimensional kinematics problem and the role of metacognition in problem solving process of one-dimensional kinematics. The findings revealed there are twenty-four demonstrated behaviours in problem solving process of one-dimensional kinematics. They are (1) Reading, (2) Rereading, (3) Reading with strategy (4) Arranging information (5) Making sense of the problem (6) Drawing a sketch, (7) Listing prior knowledge, (8) Emphasising the goal, (9) Determining the formula, (10) Determining the variable, (11) Formulate the plan, (12) Breaking down the plan, (13) Reflecting on the plan, (14) Relating the concept,

(15) Deliberating the formula, (16) Deliberating the variable, (17) Assessing the plan, (18) Recognising error, (19) Making simple calculation, (20) Doing algebra calculation, (21) Assessing the computation (22) Reflecting on oneself, (23) Speculating the answer, and (24) Answering, which serve as a dynamic and iterative cycle. Second, twelve metacognitive behaviours –rereading, reading with strategy, arrange the information, draw a sketch, making sense of the problem, relating the concept, speculating the answer, formulating the plan, breaking down the plan, assessing the plan, reflecting on the plan, and assessing the computation– were identified during problem solving process. Each student also exhibited different pattern and number of metacognitive behaviour while solving the different problem of one-dimensional kinematics. Last, analysis the use of metacognitive behaviour suggests the three roles of metacognition in problem solving process of one-dimensional kinematics, which are (1) enables student to construct an understanding of the problem, (2) enables student to regulate their action during problem solving, and (3) enables student to monitor their progress during problem solving. Thus, metacognitive behaviour should be integrated into the problem solving teaching to improve students' performance of problem solving.

CHAPTER 5

DISCUSSION AND CONCLUSION

5.1 Introduction of the Chapter

In this chapter, the summary of the study, discussion of the findings, conclusion, the implication of the findings and the suggestions for future research are presented. The first section will summarise the study. In the following section, the findings obtained through the study are discussed and the conclusion will be drawn. Last, the implication of the study and future research recommendations are presented.

5.2 Summary of the Study

Researches reported that students in the teacher training program showed poor performance in Physics problem solving (Siswono et al., 2016; Sutarno et al., 2017; Fitriyanto, 2018; Zainuddin, 2018). Siswono et al. (2016) argue that majority of the students' weakness in problem solving is not coming from lack of content knowledge rather lack of sense in choosing the effective problem solving strategy and assessing their own strategy which those skills are related to metacognition. Azizah and Nasruddin (2018) also found that teachers are not training metacognition to their students during problem solving process due to the difficulties in empowering metacognitive skills. Researchers suggest that explicit instruction of metacognition in problem solving is needed (Arias, 2017; Azizah & Nasruddin, 2018; Matene, 2018). Designing metacognitive explicit instruction requires preconception data about students'metacognition in problem solving in the relevant domain. While resources about metacognition in the problem solving process for a particular topic such and in the context of university students are scarce. Thus, this study attempt to gain insight into metacognition in problem solving process of one-dimensional kinematics among physics pre-service teachers. One-dimensional kinematics was chosen as a topic under investigation because it is the first topic in Physics. This study guided by two research questions, (1) What are metacognitive behaviours that students exhibit while solving one-dimensional kinematics problem?; (2) What is the role of metacognition in problem solving process of one-dimensional kinematics?

A qualitative study was employed to address those research questions. This study designed to look into students' problem solving process in which students engage while solving one-dimensional kinematics problem. Six students from Physics Education programme was selected to participate in this study. Think-aloud, semi-structured retrospective interview, observation, and analysis of students' answer sheets were used as data collection technique. A set of one-dimensional kinematics problems were used as data collection tool. The students were given the problems and were instructed to solve them and verbalise their thought during problem solving process. The researcher observed the student throughout the process. After the problem solving process done, student was interviewed by the researcher. All individual think-aloud and retrospective interviews were audiotaped. Data sources in this study included (a) transcriptions of think-aloud, (b) observation field notes, (c) transcriptions of retrospective interview, and (d) students' answer sheet. The data analysis was following Miles & Hubberman (1994) analysis procedure: (1) Data reduction, coding; (2) Data display; (3) Conclusion-drawing. The identification and categorisation of metacognitive behaviour was guided by Yimer & Ellerton (2010) framework. The trustworthiness of this study was established through triangulation and thick-rich description.

From the analysis, twelve metacognitive behaviours that students exhibit were found, they are: rereading, reading with strategy, arrange the information, draw a sketch, making sense of the problem, relating the concept, speculating the answer, formulating the plan, breaking down the plan, assessing the plan, reflecting on the plan, and assessing the computation. The analysis also suggests the role of metacognition in problem solving process of one-dimensional kinematic in this study, (1) metacognition enables student to construct an understanding of the problem, (2) metacognition enables student to regulate their action during problem solving process, (3) metacognition enables student to monitor their progress in problem solving.

5.3 Discussion of Findings

In the section below, the findings of this study was discussed with reference to the literature presented in Chapter 2 and other related literature in metacognition and problem solving.

5.3.1 Students' Attempt to Solve One-dimensional Kinematics Problems

The findings of this study revealed twenty-four behaviours that generally demonstrated by students in an attempt to solve one-dimensional kinematics problem. They are (1) Reading, (2) Rereading, (3) Reading with strategy (4) Arranging information (5) Making sense of the problem (6) Drawing a sketch, (7) Listing prior knowledge, (8) Emphasising the goal, (9) Determining the formula, (10) Determining the variable, (11) Formulate the plan, (12) Breaking down the plan, (13) Reflecting on the plan, (14) Relating the concept, (15) Deliberating the formula, (16) Deliberating the variable, (17) Assessing the plan, (18) Recognising error, (19) Making simple calculation, (20) Doing algebra calculation, (21) Assessing the computation (22) Reflecting on oneself, (23) Speculating the answer, and (24) Answering. These behaviours serve as dynamics and iterative sequence. A comparison was made between established problem solving models and the behaviours that students demonstrated in this study and summarised in Table 5.1. Polya's model (1945) which was widely used as a framework in problem solving research and two Physics problem solving model proposed by Heller and Heller (1995) use as a comparison model.

Table 5.1

Comparison of established problem solving model with the findings

Polya (1945) Mathematics	Heller & Heller (1995) Physics	Demonstrated Behaviours in this study
Understanding the problem	Focus the problem	Reading, Rereading, Reading with strategy
	Describe the Physics	Arranging information, Making sense of problem, Draw a sketch, Relating the concept
Devising a plan	Plan the Answer	Formulate the plan
Carrying out the plan	Execute the Plan	Making simple calculation, Doing algebra calculation
Looking back	Evaluate the answer	Assessing the computation

The table shows that the behaviours that students demonstrated to solve one-dimensional kinematics problems in this study are in line with both of established problem solving model. Polya first step is understanding the problem, this is consistent with what was found in this study for every student. Students in this study do the rereading, reading with strategy, arrange information, draw a sketch, making sense of the problem and relating the concepts to understand the problem. Some of them also restated the problem into something easier for them to understand. However, none of the students employed the second steps suggested by Polya which was trying to solve some related problems and changing parts of those problems to relate them to the present problem. In executing the plan, Polya not only suggested that solvers check their steps but also prove that their steps are correct. In this study, students were found to check their computation but none of them was found to check their steps or justify it.

Comparing the findings of this study with Heller and Heller's (1995) problem solving model which is related to university Physics, the Logical Problem-Solving Strategy focused more on determining the correct Physics concepts rather than mathematical calculation. This strategy recommends that problem solvers represent the problem in another simple manner or diagram. This has been performed by a few of the students in this study. The strategy also suggests that solvers should describe their approach and predict the outcome but none of the students in this study explicitly demonstrated this characteristic.

The next step of Heller and Heller is to use related Physics equations to solve the problem. This was consistent with what students do in this study, all of them solve the problem using the Physics formula. In the next step, Heller and Heller advised solvers to perform the algebra of the equation and it was found that all students can perform algebra while solving one-dimensional kinematics problems. Majority of the students do not find it difficult to plug in the right numbers into an equation but their weakness related to choosing the formula, some of them are using wrong formula while carrying the computation to solve the problem. There were also a few students who were aware of the importance of writing down the units of measurement for their computation, especially during the calculation. Majority of the students write the unit after finished the computation or after they get an answer. For evaluate the answer, majority of the students who performed assessing the computation, only check their calculation and answer but not justify the reason of the answer.

Some of the students in this study were found to check their computation result however, none of them tried to justify their steps or their entire problem solving process as suggested by both models. Majority of the students of this study were found to check their calculation, but no one was found to check their steps or the entire problem process to justify their answer. This is in line with Phang (2009) who also conducted a study in physics problem solving and believed that some students who did not justify their answer might be using computation as their justification for their steps and answer, for these students, there was no need for them to check again after they completed all of their problem solving if they are already checking the computation.

From the comparison, it shows that some of the students already possessed the problem-solving steps and instructions recommended by these established successful problem-solving models in Physics and mathematics. Since these steps have been recommended by scholars as good practice for problem-solving and some examples show that students are able to perform them, it may be suggested that the problem solving behaviours identified in this study are relevant to Physics Education students and can be learnt and applied to solve one-dimensional kinematics problem more effectively.

The problem solving behaviours identified in this study also align with the study of Docktor et al. (2016) which described five general problem solving process that employed by Physics university students, organises information given in the problem into useful information to solve a problem, selecting a suitable concept, employing the concept to a particular term of the problem and utilising suitable mathematical equation, last evaluating the solution. Organise information in the problem into something useful to solve the problem was employed by all students in this study during reading or after reading the problem by writing down the information form the problem in physics symbol. Selecting appropriate concepts also found while students found deliberate and determine the formula and variable. Applying the concept to particular conditions and using mathematical operations appropriately were found while students made the calculation. Last, evaluate the solution, students in this study assess their computation to evaluate the solution.

The finding of this study also showed that most of the students determine the formula by findings the equations that match the variables given in the problem. This strategy has been termed as Rolodex strategy by Bunce, Gabel and Samuel (1991). The Rolodex strategy also used by university students in Ogilvie's (2009) and Reddy's (2019) study. Ogilvie (2009) reported that first-year students of Physics programme solved the problem by utilising the Rolodex scheme where they match the variables in problem with formula that they remember to find the answer while solving their physics problems.

The findings of this study also suggest that each student have their own way to solve the problem. Because even the same student was found to demonstrated different behaviours across the problem. According to Dostál (2015), when an individual facing a problem, s/he accesses to his/her cognition about *what causes it and how to deal with it.* S/he would think about the kind of resources s/he has, how s/he can use them properly, and what way s/he should choose to solve it. These various acts of thought process and situation in the problem (whether it is difficult, easy, or moderate) is being judged by the individual and according to it he/she chooses the form of the individual behaviours. The distinctiveness of the circumstances of the problem for different individual is being reflected in the problem solving behaviours. Hence, the difference in problem solving behaviours demonstrated by the students shows their different individual characteristics and degree of understanding of the problem.

5.3.2 Metacognitive Behaviour that Students Exhibited while Solving One-dimensional Kinematics Problem

The study reported twelve behaviours that considered as metacognitive behaviours that students exhibited while solving one-dimensional kinematics problem: rereading, reading with strategy, arrange the information, draw a sketch, making sense of the problem, relating the concept, speculating the answer, formulating the plan, breaking down the plan, assessing the plan, reflecting on the plan, and assessing the computation.

The first identified metacognitive behaviour in this study is rereading. Kuzle (2015) who conducted a study to examining metacognitive behaviour in dynamic geometry problem solving was also classified reread as one of metacognitive behaviour. Kuzle (2015) found that the participants in her study often reading back the problem to review the problem or to see if they forgot important information from the problem. According to Kuzle (2015) reread is part of problem solver strategy to control potential misstep during the problem solving process and this control strategy is a metacognitive behaviour.

Metacognitive behaviour such as arrange information, draw a sketch, making sense of the problem and relating the concepts also found in Kuzle (2015) study. These metacognitive behaviours were important and contributed to move the problem solver thinking in understanding the problem and make a choice of perspective how to deal with the problem and how to select an appropriate plan to solve the problem. This argument also aligns with other studies (e.g., Artzt & Armour-Thomas, 1992; Schoenfeld, 1982).

All of the six metacognitive behaviours that belong to the engagement phase involved in activities that aim to understand the problem at the early phase of the problem solving process. This is consistent with the first behaviour in Garofalo and Lester (1985) framework, although Garofalo and Lester (1985) used comprehension strategy to describe the behaviour where student are involved in activities that aim to understand of the problem during the initial encounter with the problem. . Garofalo and Lester (1985) categorised these behaviours under the 'Orientation' phase. Garofalo and Lester (1985) called the behaviour under this phase as a strategical behaviour because they were used to understand the problem situation.

These behaviours also found in Demircioglu, Argun, and Bulut (2010) and Sagirli (2016), both conducted a study to assess pre-service teacher metacognitive behaviour in mathematical problem solving. Demircioglu et al. (2010) found that orientation behaviours have a high frequency in participants' problem solving, meaning the majority of students perform orientation behaviour. Sagirli (2016) reported that the participants in the early phase of mathematic problem solving process, demonstrated a few of reading behaviours while they trying to understand the problem.

The next behaviour is 'speculating the answer', the behaviour is aligned with 'making conjecture' behaviour in Yimer and Ellerton (2010) framework. Formulating the plan, breaking the plan, assessing the plan and reflecting on the plan, all of these behaviours are related to making planning. All existed metacognitive framework categorised behaviour that related to planning as metacognitive behaviour (Garofalo & Lester, 1985; Artzt & Armour-Thomas, 1992; Goos, 2002). These findings are also consistent with Sagirli (2016) who found that in mathematic problem solving, most of the students demonstrated 'making plan' behaviour to solve the problem. Assessing the computation was found in students problem solving during or after the computation. All established metacognitive framework ((Garofalo & Lester, 1985; Artzt & Armour-Thomas, 1992; Goos, 2002) also considered the behaviour as metacognitive behaviour. The behaviour also found demonstrated by participants in Sagirli (2016) study.

The findings also show inconsistencies in the metacognitive behaviours students exhibited across problems. A student who appeared to exhibit certain metacognitive behaviours with one problem, then showed poor metacognitive behaviours when attempting other problems, or less frequently showed no metacognitive behaviours at all. These findings align with the result of Karnain's (2014) study. Karnain (2014) found that students exhibited different kinds and level of sophistication of metacognitive behaviour. He continued that the inconsistencies observed may be attributed to students' immaturity in handling emerging metacognitive behaviours. The difference in exhibited metacognitive behaviour also could be the effect of different individual characteristic as a problem solver. According to Karnain (2014), student's different levels of metacognitive behaviour reflect his/her characteristics as a beginner or proficient problem solver.

The findings also suggest that the different metacognitive behaviour among students also reflect their performance levels. Students who frequently exhibited metacognitive behaviour were found gave the correct solution at the end of problem solving. This is consistent with Abdullah (2017) research. Abdullah (2017) who scrutinise students' metacognitive behaviour in mathematical problem solving found that successful students demonstrated metacognitive behaviour more frequently during problem solving process than unsuccessful students. However, Goos (2002) also stated that the quality of metacognitive behaviour also contributed to problem-solving success or failure. This case also found during this study, some students who failed to solve the problem do exhibit the metacognitive action but it was categorised as insufficient metacognitive behaviour such as some students do one or two-act of planning (emphasise the goal) but their behaviour could not be categorised as 'formulated the plan'.

The study also found that one or more metacognitive behaviours were identified in each students' problem solving and affect the problem solving process. This finding is supported by several researchers who agreed that metacognitive actions are considered to be the "driving forces" during the problem solving process (Garofalo & Lester, 1985; Schoenfeld, 1982; Silver, 1982; Yimer & Ellerton, 2010; Phang, 2009).

The identification of metacognitive behaviour in this study was guided by Yimer & Ellerton framework (2010) which provided detailed metacognitive behaviour in five-phase of problem solving. Findings of this study showed that metacognitive behaviour only found in four phases: engagement, transformation-formulation, implementation and evaluation. None of identified metacognitive behaviours in this study belongs to internalisation phase. Internalisation phase is a phase where students reflect on the entire solution process. It means students in this study do not exhibit behaviour that aims reflect their entire problem solving process. As mentioned above, the majority of students in this study were found to check their calculation, but no one was found to check their steps or the entire problem process to justify their answer. It also evident that more metacognitive behaviours were identified during the engagement phase, that showed that students spend more time doing the orientation activities than evaluation activities, it aligned with Stillman & Galbraith study (1998).

5.3.3 Role of Metacognition in Problem Solving Process of One-dimensional Kinematics

This study suggests three roles of metacognition in problem solving process of one-dimensional kinematics, (1) metacognition enables student to construct their understanding of the problem, (2) metacognition enables student to regulate their action and decision during problem solving, (3) metacognition enables student to monitor her progress during problem solving.

First, metacognition enables the student to construct their understanding of the problem. The findings of this study suggest that students who exhibited more metacognitive behaviour in early steps of 'Reading' are found to build a meaningful understanding of the problem and gave the correct answer for the problem. These findings are consistent with a study of Lester, Garofalo & Kroll (1989), they found the excellent problem solvers focused on building a meaningful understanding of the problems while the novice problem solver usually focused on trivial understanding. The finding is also supported by Sagirli (2016) who reported that the participants claimed that metacognitive support helps them understanding and detailing the problem also reach the alternative ways of solution.

Second, metacognition enables the student to regulate their action during problem solving. Students who found formulating, exploring, and reflecting on the plan were able to regulate their action and decision by modified the formula during the computation in problem solving. This finding is consistent with Barbasena and Sy (2015) who reported that metacognitive regulation was one of the function they found during problem solving of Education programme students. They stated that metacognitive regulation occurs when students modify their strategy. The finding also supported by Lester et al. (1989) who stated that metacognition is actually regulation of individual's behaviour during problem solving and it related to action and decision attempted in problem solving process. For example, revising or abandoning unproductive plan or strategies.

Last, metacognition enables the student to monitor her progress during problem solving. A student who was found to keep track of her problem solving by assessing her plan, checking and evaluate her computation, in the result when she made mistake, she immediately realised that and fixed the mistake. This incident found in several problem solving case during this study such as Tara, Dayu and Nina. Barbasena and Sy (2015) also reported metacognitive evaluation as one of metacognitive function found in their research. The findings also in line with Rickey and Stacey (2000) who conducted a study about the role of metacognition in Chemistry learning. They reported a student who has sufficient knowledge to find a solution for the problem and came into an incorrect solution because she did not attempt to verify her work. According to Schoenfeld (1985), efficient problem solver keep tabs of how good things are functioning as his/her execute the plan. If things are going smoothly, they continue; if they encounter the trouble, it means they need to evaluate the plan and consider an alternate option.

A comparison was made between roles of metacognition suggest in this study and the role of metacognition stated by a few previous researchers, as showed in the table below.

Table 5.2

Comparison of Role of Metacognition in Problem Solving

Role of Metacognition in Problem Solving quoted by previous researcher	**Role of metacognition suggest in this study**
• Meltcafe (1994) Metacognition helps the problem solver: (1) recognise that there is a problem to be solved, (2) figure out what exactly the problem is, and (3) understand how to reach a solution. • Lesh & Zawojewski (2007) Metacognition helps students develop better understanding • Jacobse & Harskamp (2009) Metacognition improving problem solver's understanding and the use of appropriate strategies	Metacognition enables the student to construct their understanding towards the problem.
Lester, Garofalo & Kroll (1989) Metacognition allow students to monitor and regulate their problem solving activity	Metacognition enables the student to regulate their action during problem solving. Metacognition enables the student to monitor and evaluate her progress during problem solving.

The comparison shows that role of metacognition that suggest in this study align with the role of metacognition stated by the previous researchers. Findings also indicated that metacognitive behaviours identified in this study play roles in the problem solving process. It is evident that student who exhibited more sufficient metacognitive behaviours during problem solving tend to show good problem solving performance. These already explained by Schoenfeld (1985) framework. In his framework of problem solving, Schoenfeld included metacognition as one factor that predicting the result of students problem solving. A failure that happened during problem solving when the problem solver has sufficient knowledge is the result of insufficient metacognitive that suppress the suitable usage of the knowledge (Schoenfeld, 1985). Metacognition, according to Schoenfeld (1985), refers to the metacognitive behaviours (regulation of cognitive activities), such decision-making that individual take concerning if (evaluating), when (planning), and how (monitoring) they will utilise his/her knowledge (resources), and strategy (heuristics) while made an attempt to solve the problems.

5.3.4 Additional Discussion

During this study, there are a few particular cases that caught the researcher's attention and curiosity. First, there are a few cases where students found only focused on computation and do not take time to analyse the problem or made a plan. This case concurs with Stillman & Galbraith (1998) study. The results of their research indicated that typically students spend more time doing the orientation and implementation activities than doing organisation and evaluation activities. Such students, according to the Stillman & Galbraith (1998), were preoccupied with the mechanics of executing a solution rather than with planning, monitoring, and verification strategies.

Second, there also one case of students that found confidence with her answer and take the shortest time to solve the problem. However, turn out that all the solution she gave were wrong. Ironically, during the retrospective interview, she perceived the problem as an easy problem. This case can be explained by Efklides

(1998) research. According to Efklides, the case could happen because of the delusion of difficulty of the problem. This feeling appears because the student recognises a similar problem or the student does not comprehend the problem requirements. As a result, the student can not empower the essential attempt to solve the problem successfully. It shows that students' affective state also appeared to relate to their metacognitive behaviour. Kruger & Dunning (1999) stated that conversely, there is an individual (children or adult) who is very confident with their answer despite their insufficient knowledge about the topic. This overconfidence feeling suggests their overappraisal of their knowledge or lack of their consciousness of their insufficient knowledge. It shows that the individual lack of metacognitive awareness.

The last case was when a student assessed her computation, she found her answer was not logic because the value was too big. However, she ignored this fact and continued her computation. At last, she failed to give the correct solution. This case was explained by Goos (2002). Goos (2002) called this case as 'metacognitive failure', refers to an incident where students who have metacognitive activities in their problem solving but they still fail to do metacognition. The student already did metacognitive behaviour by assessing her computation, but she ignored her miscalculation. Her poor decision lead to unsuccessful problem solving.

5.4 Conclusions

Metacognition is an important aspect of the problem solving process. The goal of this study was to understand the metacognition that occurs within the problem solving process of one-dimensional kinematics. This study utilised think aloud technique to observing students' metacognitive behaviour while they engage in the problem solving process and then scrutinise how these metacognitive behaviours help student completed their problem solving. Twelve metacognitive behaviours have been identified through this qualitative study namely rereading, reading with strategy, arrange the information, draw a sketch, making sense of the problem, relating the concept, speculating the answer, formulating the plan, breaking down the plan, assessing the plan, reflecting on the plan, and assessing the computation. These identified metacognitive behaviours were found to help students to construct an understanding of the problem, regulate their action during the problem solving process, and monitor their progress in problem solving. Both of these outcomes contributed directly to the goal of this study, by providing insight into metacognition occur in one-dimensional kinematics problem solving process. This study achieves the objectives of the study. Furthermore, this insight will help the development of an educational intervention that foster the metacognitive behaviour that enables students to progress within real problem solving task.

5.5 Implication of the Study

The findings of this study have a few implications in the educational field. Thus, the area where this study may contribute towards the theory and teaching will be identified.

5.5.1 Implication for Theory

The finding of this study builds materials for body knowledge by providing:

5.5.1.1 Preconception for Future Research

This study sought an understanding of metacognitive behaviour in one-dimensional kinematics problem solving. Thus, the findings of this study provide a basic assumption for future research on metacognitive behaviour during problem solving and instructional intervention on problem solving using metacognitive. Particularly, the findings of this study serve as preconception towards future research on designing metacognitive explicit instruction to improve problem solving performance.

5.5.1.2 Resource for Understanding the Metacognitive Behaviors in One-dimensional Kinematics Problem Solving

Although this study has not reached theoretical saturation, the result of this study has identified a few metacognitive behaviours in one-dimensional kinematics. A few previous researchers have studied the metacognition in the physic problem solving process however, the population and the topics they used were quite different from the ones used in this study. However, this study identified metacognitive behaviours of first-year university students of Physics Education programme for one-dimensional kinematics topic. As the subject and focused topic in this study is specific, the findings of this study have shown it to be a valuable resource to understand the metacognitive behaviour of students while they engaged one-dimensional kinematics problem solving.

5.5.2 Implication for Teaching

5.5.2.1 Integrated Problem Solving Instruction

Problem solving is widely recognized as a central focus of Physics curricula. Teaching in university Physics education programs means carries double responsibilities, first, to help develop the problem-solving skills of the students, and to prepare these students who are expected to teach for the problem-centred classrooms. Since the problem solving behaviour that students demonstrated in this study in line with what had been recommended by scholars as good practice for problem-solving, it may be suggested that these behaviours are relevant to Physics Education students and can be learnt and applied to solve one-dimensional kinematics problem more effectively.

5.5.2.2 Designing Metacognitive Explicit Instruction

The metacognitive behaviour identified in this study can be used as a foundation for designing metacognitive explicit instruction in the university classroom. It also can be used to establish the kind of environment for encouraging the development of metacognitive behaviours during problem solving.

5.5.2.3 Assessment of Metacognitive Behaviour

The finding of this study also provides documentation of metacognitive behaviours when students were solving a problem. It is to derive a catalogue of verbal utterances and actions which aims to serve as an empirical framework for teachers to detect the occurrences, or absence of metacognitive processes amongst students while assessing students.

5.6 Suggestion for Future Research

This study was focused only on metacognition on one-dimensional kinematics problem solving. Thus, more researches are needed to follow up on numerous issues about metacognition in problem solving. Based on the findings discussed in this study, a few suggestions are recommended for future research, they are:

1) Since the first intention of this study is to get preconception data to develop metacognitive explicit instruction for problem solving, a study that aims to develop explicit instruction according to preconception from the findings of this study.
2) A grounded theory can be conducted to examine the dimensions and elements transpired from this study in order to achieve theoretical saturation by doing a further investigation with larger theoretical sample.

3) A quantitative measure also can be done to examine metacognitive behaviour in one-dimensional kinematics problem solving. The validity of the findings can be established by carrying out studies with a larger sample of students.
4) This study focused only on one-dimensional kinematics topic. It would be interesting to explore wider scope such as kinematics or mechanics by adding a number types of physics problem.

5.7 Summary

This chapter consists of a summary of the study, discussion about research findings, conclusion, implication, and suggestions for future research. There are twelve metacognitive identified in this study and these metacognitive behaviours helps student complete their problem solving. The metacognitive behaviours identified in this study align with previous studies in the same topic. Result of previous studies also support the role of metacognition that discussed in this study. This study has a theoretical and practical implication for the problem solving teaching. The theoretical implication presented in the form of resources to understanding the metacognitive behaviors in one-dimensional kinematics problem solving. The practical implication is the finding of this study can be developed to be a problem solving instruction based on metacognitive or as guide to assess student metacognitive behaviour. In the end, the research suggests future research by doing a further investigation with larger theoretical sample to reach theoretical saturation.

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