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Exploring the Metacognitive Skills of Secondary School Students' Use During Problem Posing

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Abstract

The purpose of our study was to explore students' use of metacognitive skills during problem posing activities. This qualitative research explored the metacognitive skill of 21 secondary school students in a rural Anambas Indonesia while posing individually mathematical problems. Thinking-Aloud protocol was conducted during the problem posing activities. The audio recordings of Thinking-Aloud protocol for the students provided the data to address this question. Analysis of their written work and Thinking-Aloud protocols provided evidence of how students used metacognitive skills while problem posing and revealed different levels of these skills. Analyses of the Thinking-Aloud protocol also provided evidence for the metacognitive skills associated with planning, monitoring, and evaluation. The students used planning and monitoring skills equally. Furthermore, different levels of sophistication of planning were apparent. Students who combined these metacognitive skills demonstrated a higher level of monitoring. However, from our analyses that there was considerable overlap in the metacognitive activities associated with monitoring and evaluation.

Keywords: Metacognitive skill; problem posing; secondary school students

Abstrak

Tujuan kajian ini adalah untuk meneroka kemahiran metakognitif yang digunakan oleh pelajar semasa aktiviti pengutaraan masalah. Kajian kualitatif ini telah meneroka kemahiran metakognitif 21 pelajar sekolah menengah di kawasan luar bandar di Anambas Indonesia semasa mengutarakan masalah matematik secara individu. Protokol Pemikiran Bersuara telah dijalankan semasa aktiviti mengutarakan masalah. Rakaman audio pemikiran bersuara untuk pelajar juga telah menyediakan data bagi menjawab soalan kajian ini. Analisis kertas kerja pelajar dan pemikiran bersuara telah memberikan bukti bagaimana pelajar menggunakan kemahiran metakognitif semasa aktiviti pengutaraan masalah dan telah mengungkapkan pelbagai peringkat kemahiran-kemahiran ini. Analisis Protokol Pemikiran Bersuara telah memberikan bukti bagi kemahiran metakognitif yang berkaitan dengan perancangan, pemantauan, dan penilaian. Pelajar telah menggunakan kemahiran merancang dan memantau sama rata. Tambahan pula, tahap yang berbeza sofistikated perancangan tampak jelas. Pelajar-pelajar yang telah menggabungkan kemahiran metakognitif menunjukkan tahap pemantauan yang lebih tinggi. Walau bagaimanapun, daripada analisis kami bahawa terdapat tumpang tindih dalam aktiviti metakognitif yang berkaitan dengan pemantauan dan penilaian.

Kata kunci: Kemahiran metakognitif; pengutaraan masalah; pelajar sekolah menengah

1.0 INTRODUCTION

Today's dynamic society requires school graduates who are able to adapt to new, frequently unpredictable situations (such as changing jobs, changing homes, and changing professions many times during a lifetime) and to make knowledgeable decisions in those situations (Singer, Ellerton, & Cai, 2013). Kilpatrick (1987) noted: "In real life outside of school […] many problems, if not most, must be created or discovered by the solver, who gives the problem an initial formulation" (p. 124). Prior scholars derived learning efficiency from repeated question and answer sessions where subsequent questions and answer were utilised in gauging the level to which intelligent thinking and idea formation were improved (Socrates, 469 BCE– 399 BCE). Over the years, the similar processes of how an individual natural thought process remains a focus of contemporary education (Singer *et al.*, 2013).

Seemingly, in the field of mathematics, the educational modalities place overly huge emphasis on the path to problem solving in terms of rights and wrong, rather than the individual intelligent thinking process (Schoenfeld, 1989). In most cases teachers tend to emphasize skills, rules and procedures, which become the essence of learning instead of instruments for developing understanding and reasoning (Ernest, 1991). Mathematical problem presented to student in the classroom on a daily basis most often than not possess perpendicular bearings to problem faced in real life (Lave, 1988; Roth & McGinn, 1997). Instructors often look towards textbooks which in turn, provides instructors with well-structured questioned that present contrary problems to those faced by students in real life due to the openness and unstructured nature of real life problems. Instructors shy away from utilizing problem posing in the classrooms due to their inability to generate the problems and the know how in effective utilization in the classroom skills (Leung & Silver, 1997). Therefore, since instructors lack the required know how in problem posing, student training are limited in scope to cover provision of plain answers to which are expected by the instructor rather than intelligent thinking. This trend often leads to students' misapplication and system failure (Semadeni, 1986).

Subsequent researchers have stressed the need for problem posing as opposed to rigid textbook questions geared at improving tool in pedagogy for mathematical instructing (Brown & Walter, 1983; Kilpatrick, 1987; Krutetskii, 1976). Similary, seminar authors have expressed the dire importance of mathematical task for effective mathematics instructing (Silver, Mamona-Downs, Leung, & Kenney, 1996; Akay & Boz, 2010). Intelligent thinking is born through challenging posed problems presented to students in the classroom. A comparison of the student behavior revealed that the line of thought was shaped in classroom is the constant computation exercise that leads to misinterpretation of mathematic as carrying out sets of regular procedures.

The ability of a student to create their own mathematical problems denotes the will power to increase in their level of understanding and a widow to their thought process on how they perceive mathematics in real life situations (Ellerton & Clarkson, 2007). In an unconventional twist expressed by prior researchers, instructors now use the posed problem by students to gauge their level of mathematical understanding (Barlow & Cates, 2006; Lin, 2004; Toluk Ucar, 2009). In his doctorate dissertation, Kwakwa (2012) argued that by adopting the "Problem Posing Approach" students tended to be innovative, skilful and knowledgeable and problem solvers. More importantly, Brown and Walter (2005) believed that the power of utilizing problem posing is thought to transform the way mathematic is been taught from the old traditional answer presenting following stipulated guideline to generating questions from a diverse number of endless imaginative ideas.

Mathematical successes are no longer viewed in terms of how much knowledge is applied but an embodiment of cognitive strategies and metacognitive behavior from students (Hammouri, 2003; Schoenfeld, 1985; Zimmerman & Bandura, 1994; Schunk & Zimmerman, 2007). Similar views add to the clarion call for the need to extend mathematical teaching to boarder on development of metacognition (Jager *et al.*, 2005). The development of process based instructions proffer actions on instructing, planning and evaluating problem tasks (Ashman & Conway 1993). The medium of presentation, guide, materials and techniques determine the metacognitive growth rate experienced by students (Paris & Paris, 2001). Thus, exposing students' metacognition during problem posing activities is a necessary step from theory to reality, i.e. posing questions.

Metacognition is about self-regulation, not regulation by others. The concept is on a global increase in the educational sector. Interestingly, Partnership for 21st Century Skills supported the self-directed learning methods. Recommending self-directing as a key ingredient to arming students with the necessary skills to survive life after universities till future work environment (Lai, 2011).

In mathematics education, the major goal of implementing metacognitive is to help students develop knowledge and awareness of their own thought processes (Nelson, 2012). Students without metacognitive approaches are basically learners without direction to review their progress, complishments, and future directions (O'Malley *et al.*, 1985).

Metacognitive skills are tools that empower the learner. Pupils very often fail to see learning as cycle that involves revisiting previous work to see where it can be improved, acknowledging the value of mistakes, and planning improvements on this basis (Dweck, 2002). By showing a learner that they can be in control of how they study, how they organise their work, and how they reflect upon it, we encourage them to take responsibility for learning and demonstrate that it is an active process reduce the "mystery" that some pupils imagine shrouds the learning process. Learning doesn't just "happen" if you sit in a classroom for long enough or read the same page enough times. The self-regulatory skills of planning, monitoring and evaluating are crucial for the student if they are to experience learning in the holistic manner intended in the learning cycle. Consequently, Gourgey (1998) recommended that instruction must encourage students to generate and use their own strategies and self-questions.

Despite evidence that metacognition is important for high-quality learning in classrooms (Tobin and Gallagher, 1987), classrooms are often characterized by absence or lack of characteristics necessary for developing and enhancing students' higher order thinking and metacognition, and by overemphasis on memorization and lower order thinking and learning (Kaberman dan Dori, 2009). According to Everson and Tobias (2001), as well as Matanzo and Harris (1999), many students entering college have not been taught strategies for examining or improving their metacognition. In fact, a study of pre-service teaching students conducted by Matanzo and Harris reports that many students do not even know what metacognition is. Hartman (2001) contends that students cannot be expected to be competent with metacognitive skills because these skills are rarely taught explicitly and not everyone develops them independently. He also reports that many students experience academic difficulty because they constantly focus on retaining subject matter content without first learning the metacognitive skills needed to support that effort.

Other Studies also indicate that few students engage in the processes of metacognition in a manner that would help them be successful at problem solving. Schoenfeld (1992) examined how students worked through problems that were not familiar to them and found that many spent very little or no time on planning during problem solving. Students would read the problem, consider some method of solution and use it without regard to whether it was leading them to a solution. Stillman and Galbraith (1998) identified the same lack of planning by students in their research. Such learners when faced with challenges to which their initial thought solution fails discard the initial solution for a new method without first tracking thoroughly why the first method failed. This action contributes to diminishing metacognition by learners (Schoenfeld, 1985).

Past research on metacognition much has been written on the areas of metacognition within problem solving setting (eg. Swanson, 1990; Schoenfeld, 1992; Foong, 1993; Stillman & Galbraith, 1998). However, there is limited literature on metacognition related directly to problem posing settings. They also stress the need for problem posing (Brown & Walter, 1983) and what are called 'inquiry skills' which include questioning and reflective discussion (Lipman, 1985). If metacognitive skills appear to be relevant in Mathematics problem-solving among students, then it seems likely that metacognitive skills may play a role in aiding secondary school students when posing mathematics. This presents the learners with the skill of cognition through question asking and metacognition through monitoring of the eventual outcome (Flavell, 1976).

Againts this background, the purpose of this research is to answer the research question: "What kinds of metacognitive skills occur during problem posing activities among secondary school students?" More specifically, this research has an objective: To investigate students' metacognitive skills while posing mathematical problems. To investigate this question, we adopted Schraw *et al*. (2006)' model of metacognition because it aligns well with the problem solving process. Therefore, by using This qualitative research and data sources that include a think aloud protocols, semi structure interview, and students written works, we endeavored to capture a rich picture of students' thinking while problem posing. In addition, this research is delimited to problem reformulation. The finding of this research has potential to enrich our understanding of how students apply metacognitive skills during mathematical problem posing activities and are expected to assist teachers in developing a creative lesson plan by proposing high level problems to students and increasing teacher's awareness of the need for collaboration with metacognitive skills during teaching and learning mathematics. The rest of article is structured as follows: first, a decription of the research methods and procedures used in the study, the findings of our enquiry are then discussed. Next, the paper concludes with a conclusion and discussion. Finally, directions for future research are offered.

■2.0 METHODOLOGY

This qualitative study examined the metacognitive skills of secondary school students while mathematical problem posing activities. Participants in this study consisted of a convenience sample of 21 secondary school science students in Anambas Regency in Kepulauan Riau (Indonesia). Since the aim of the study was to examine the metacognitive skills rather than simply assess mathematics expertise, it was necessary to supply a nonroutine problem that would challenge the students. The question was adapted from the Stickles (2006) (see figure 1). As Nelson and Narens (1990) suggest, the main tool to generate data about a person's metacognition is from their own reports about their thinking. Hence, students' metacognitive skills were assessed using a Thinking-Aloud protocol, interview and test. The purpose of the Thinking-Aloud protocol was twofold. First, the sessions were part of the intervention by giving the students an opportunity to become more aware of their thinking while problem posing by articulating their thinking. Second, these sessions provided a source of data to address the research question to examine the metacognitive skill of students during problem posing. The data collections were administered in the third two weeks of the semester in 2013. After students written works were analyzed, the two problem posers were individually interviewed to probe the metacognitive skills that occurred during problem posing.and to examine particularly the responses to statements implicitly assessing the metacognitive processes expressed by the students while posing the problem. 2 out of 21 respondents were subsequently interviewed for a period of 2 hours during which period the learners had liberty to pose a series of problems. The subjects were first asked to pose as many problems as they can. The interviewing methodology was adapted from Ericsson and Simon (1993). Namely, each subject was required to think aloud, and if she or he kept silent for more than 20–25 s while working on the task, the interviewer prompted the subject by saying ''Keep talking'' or asking ''What are you doing right now?'' The interviews were conducted by two members of the research team; both used the same interview guideline. The subjects were provided with pencil-and-paper and, as a rule, made notes while working on the interview task. However, the interviewers refrained from explicitly asking the subjects to write their problems' formulations. This is because writing-by-request could slow down the subjects' thinking-aloud speech and, more importantly, could become an obstacle for those subjects who felt that they had nothing to show or write (cf. De Corte and Verschaffel 1996). During the think aloud protocol session the interviewers refrained from interfering with the thought process only during repeated silence on the path of the interviewee; this enhances spotting the metacognition of the learner. The entire process of think aloud protocol was recorded using a video machine

Each student performed one test problem while thinking aloud. This was intended to help students get used to the procedure and the camera. This problem is not taken up in the analyses. During the actual measurement, students got two word problems (one by one) which they were instructed to pose while thinking aloud. The problems used for the think-aloud protocols was the same as it was in paper test. The question was adapted from the Stickles (2006) is presented below.

Parking Lot Flyers Instrument

The SpreadtheWord Advertising Company needs to distribute flyers for ten different businesses. They are going to place the flyers on cars in the parking lot at a nearby shopping mall. There are 1000 cars in the lot. The businesses each have their own flyer. The LotaMoney Company is paying for flyers for all the cars. Consequently, a worker places a flyer on each of the 1000 cars for them. The rest of the businesses cannot afford one flyer for each car. A second business can afford one flyer for every other car. Consequently, a second worker places a flyer from the second business on every other car starting with the second car in the lot. A third business can afford one flyer for every third car, and a worker places a flyer from the third business on every third car starting with the third car in the lot, and so on. How many cars would be necessary so that one car would get all 10 flyers?

Using the above problem, pose some related problems!

Figure 1 Example of problem-posing question from the parking lot flyers instrument (Cited from Stickles, 2006)

After having collected students' think-aloud protocols, each videotaped think-aloud session was assessed by researchers. Our analyses of the transcripts were guided by the coding, seeking patterns, and theme analysis methods described by Patton (2002). Patton (1990) states "A multimethod, triangulation approach to fieldwork increases both the validity and the reliability of evaluation data" (p. 245). After testing the students, thinking aloud, and interviewing the students individually, all data were transcribed and descriptively coded according to the categories in Holistic Education Network's (2004) metacognitive framework (planning, monitoring and evaluation). The data from the interview and thinking aloud were entered in an Excel spreadsheet and coded according to the same metacognitive framework. Different methods of data collection revealed reliable, common evidence of the participants' use of metacognition in their processes of posing mathematical problem.

■3.0 RESULTS AND DISCUSSION

During the activity, we observed that all students in the class were actively engaged in posing the problem. A small number (2 out of 21 or about 9.52%) of the students posed a problem, and the rest of those did not contain sufficient information to solve the problem. Example of the problem-posing statements posed through problem generation for the Nested Squares instrument are in Figure 2.

Problem:

A teacher set up 15 baskets. He asked the students to throw a ball in each basket, the second student to throw a ball in every other can, the third student to throw a ball in every third basket, and so on. How many baskets would have at least 5 balls in them when all 15 students have went?

Figure 2 Example of problem-posing statements from the parking lot flyers instrument

The students retained their focus throughout the duration of the activity, and they were persistent in their attempt to work through the problems. The transcripts of the audio recorded of two case students provide additional support for tha data analyses. We used the planning, monitoring, and evaluation metacognitive categories to guide our analyses of the students' data. We begin with an overview of each type of metacognitive category. We interpreted statements that referred to the given information, goal of the problem, or selection of relevant strategies as planning. For example, "Okay let me write down what I know first"(S1/student I). Monitoring was characterized by the "in the moment" checking of their work at intermediate stages. For example, "I need to make sure it's suitable"(S1). Evaluation was characterized by statements about the verification of the final answer. For example, "if the answer I get makes sense"(S2/student 2). Our analysis revealed that the students demonstrated planning and monitoring equally for thinking aloud problem posing protocols.

3.1 Planning

Examination of the transcript excerpts we coded as planning revealed the following metacognitive skills: making sense of the task, extracting the given information, being aware of the goal, seeking any examples used in the past, and mapping a solution. Within some of these skills, we noted varying levels of sophistication in the way the students employed planning strategies. We begin with evidence of the students trying to make sense of the problem before launching into their solution to the new problem. The statements that demonstrated this were: "Let me think of what's this"(S2) and "I've to write down everything first so that I can get an idea of it"(S1). "I'm thinking there's numbers in there that were not doing anything right, but I don't know if they are relevant" (S2). The students were able to identify the goal of problem. Commonly, the students restated what was asked in the problem. The language used to express this included, "I've got to determine" (S2), "I need to find out" (S1) , and "I need to find" (S2). Two comments stood out as being more interpretive. S1 expressed the goal of the problem in his own words showing that he had a clearer understanding of the problem. He said, "So I need to find out how many..." A component of planning demonstrated by the students was their identification of previous strategies that were relevant to the current problem. At an elementary level, the student referred to his notes in search of examples of related problems. As an example, (S1) commented "Give me one second, I'm just going to grab my book. Okay, see most of the examples were converted to combination". S2 took this a step further, identifying the way in which a past problem was different from the current problem: "Okay, so what I used to do was find the total of cars". S1 and S2 varied in the way they made use of previously learned strategies. At the simplest level, the students had a tendency to execute familiar questions without thinking through how that question would link to other steps that would eventually satisfy the goal of the question. Using previous knowledge in this way hindered the learners from moving forward in the new question.

3.2. Monitoring

Three types of metacognitive monitoring emerged from our analysis of the thinking aloud protokol transcripts: screening, and justification and a little revision. All monitoring began as screening where the students checked an intermediate action. Students exemplified screening with statements like, "Wait, I"ll check if it can be solved" (S1), "Oops, that doesn't make sense" (S2). Other types of monitoring were coupled to screening. We noted a number of instances where after screening, the students justified why a question did or did not make sense. In the following excerpt, S2 recognized that the question obtained was reasonable because it was in the expected domain. S2: Is that the reasonable question? S1: Well that would make sense because the numbers are almost similar with the first question and I need to start it from here. (S1 and S2). The following exchange between S1 and S2, demonstrated screening followed by revision. S1and S2 suspected an error, and S2 corrected the mistake.

S1: But that's wrong I think.
S2: Let me try another sentences
S2: Oh! That's what went wrong.

In a number of cases, the students alluded to the need to revise their approach but did not immediately know how to redirect their efforts. One example of this occurred when S2 commented, "Okay well that's really frustrating because I can't find the solution of the first question because I don't know what' the exact formula is". Other instances of this were signaled by language like: "Just one second, I've got to think about this" (S1), and "I have to think it in my head" (S2).

3.3 Evaluation

The students' comments about their new question to the problems revealed two levels of evaluation: intuition and reason. First, we present one example of what we interpreted as intuition. Common to these examples was the students' "feelings" that the answers were right or wrong. She concluded the session with, "I think I'm going to go with permutation. I've got a good feeling" (S2). In the following discussion, S2 presents two hunches. Initially, S2 mistakenly thought that the new question was a permutation could be the answer. After further consideration S2 suspected that a more rigorous approach to try to solve the new problem is required. S1 suspected that his solution was not question because it was based on an assumption. S1 noted, "And then, I assume but I didn't really, I don't know, I think I missed something". The students also using reasoning to evaluate their answer. S1 understood that the final answer for the problem could be checked by comparing its topic. In addition, S2 realized that his attempt to find the result of the new question did not match the goal of the first problem. He commented, "Yeah, but it's asking for the number of cars. That's not the correct one".

■4.0 IMPLICATIONS AND CONCLUSION

The thinking aloud protocols provided evidence of how students used metacognitive skills while problem posing and revealed different levels of these skills. Analyses of the Thinking Aloud protocols provided evidence for the metacognitive skills associated with planning, monitoring, and evaluation. The students used planning and monitoring skills equally. Planning skills included making sense of the problem, extracting the given information, identifying the goal, seeking any examples used in the past, and mapping a solution. Furthermore, different levels of sophistication of planning were apparent. Lower level planning was demonstrated when students restated the goal. In contrast, higher level planning was demonstrated when students interpreted the goal, compared the context for their use of strategies in the past to the context of the new problem. Students' different levels of planning reflect the characteristics of novice and expert problem solvers described by Heyworth (1999). The students demonstrated monitoring when they screened for errors, justified their judgments, and made revisions to correct wrong turns. Students who combined these metacognitive skills demonstrated a higher level of monitoring described by Delvecchio (2011). A part of this process included periods of reflection when the students took time out from executing actions to think about what revision actions they would pursue next. Students' attention to thinking before acting was evidence that they valued metacognitive activities as part of their problem posing process. The students demonstrated evaluation through their comments on the correctness of their final question. The students showed two levels of evaluation: intuition and reason. Intuition was the students' sense of the correctness of a solution. Reason was demonstrated when students elaborated on why a solution was correct or not. Students who were able to explain why an answer was incorrect demonstrated a deeper analysis of their solution to the problem. Reference (Kramarski, B., and Zoldan, 2008) supports the importance of students' analysis of errors as a means to reduce conceptual errors. It is apparent from my analyses that there is considerable overlap in the metacognitive activities associated with monitoring and evaluation. Both involve students checking their work. In the case of monitoring, students check intermediate actions, and during evaluation they check a final answer. Metacognitive evaluation includes students proposing alternate solutions and reflecting on what new things they learned by attempting the problem.

References

Akay, H., and Boz, N. 2010. The Effect of Problem Posing Oriented Analyses-II Course on the Attitudes Toward Mathematics and Mathematics Self-Efficacy of Elementary Prospective Mathematics Teachers. *Australian Journal of Teacher Education.* 3(2): 59–75.

Ashman, A., & Conway, R. 1993. *Using Cognitive Methods in the Classroom.* London: Routledge.

Barlow, A. T., and Cates, J. M. 2006. The Impact of Problem Posing on Elementary Teacher's Beliefs About Mathematics and Mathematics Teaching. *School Science and Mathematics*. 106: 64–73.

Brown, S., and Walter, M. 1983. *The Art of Problem Posing.* Philadelphia: Franklin Press.

Brown, S., and Walter, M. 2005. *The Art of Problem Posing.* 3rd Ed. Hillsdale, NJ: Lawrence Erlbaum.

De Corte, E. & Verschaffel, L. 1996. An Empirical Test of The Impact of Primitive Intuitive Models of Operations on Solving Word Problems With a Multiplicative Structure. *Learning and Instruction.* 6(3): 219–242.

Delvecchio, F. 2011. Students' Use of Metacognitive Skills While Problem Solving in High School Chemistry. Doctoral Dissertation, Queen's University. Kingston, Ontario, Canada.

Dweck, C. S. 2002. The Development of Ability Conceptions. In A. Wigfield & J. Eccles (Eds.), *The Development of Achievement Motivation*. New York: Academic Press.

Ellerton, N. F., and Clarkson, P. C. 2007. Language Factors in Mathematics Teaching. In: Bishop A.J *et al.*, International Handbook of Mathematics Education. Kluwer Academic Publishers, Netherlands.

Ericsson, K. Anders, & Herbert, A. Simon, 1993. Completeness of Reports. In Protocol Analysis: Verbal Reports As Data, MIT Press.

Ernest, P. 1991. *The Philosophy of Mathematics Education*. London: Falmer Press.

Everson, H. and Tobias, S. 2001. The Ability to Estimate Knowledge and Performance in College: A Metacognitive Analysis. In H.J. Hartman (Ed.). *Metacognition in Learning and Instruction*. The Netherlands: Kluwer Academic Publishers. 69–83.

Flavell, J. H. 1976. Metacognitive Aspects of Problem Solving. In L.B. Resnick (Ed.). The Nature of Intelligence. Hillsdale, NJ: Lawrence Erlbaum Associates.

Foong, P. Y. 1993. Development of a Framework for Analyzing Mathematical Problem Solving Behaviours. *Singapore Journal of Education*.13(1): 61–75.

Gourgey, A. F. 1998. Metacognition in Basic Skills Instruction. *Instructional Science.* 26: 81–96.

Gourgey, A. F. 1998. Metacognition in Basic Skills Instruction. *Instructional Science.* 26(1–2): 81–96.

Hammouri, H. A . 2003. An Investigation of Undergraduates‘ Transformational Problem Solving Strategies: Cognitive/Metacognitive Processes as Predictors of Holistic/Analytic Strategies. *Assessment & Evaluation in Higher Education*. 28: 571–586.

Hartman, H. J. 2001. Developing Students' Metacognitive Knowledge and Strategies. In H. J. Hartman (Ed.). *Metacognition in Learning and Instruction: Theory, Research, and Practice.* Dordrecht, The Netherlands: Kluwer Academic Publishers. 33–68.

Heyworth, R. M. 1999. Procedural and Conceptual Knowledge of Expert and Novice Students for the Solving of a Basic Problem In Chemistry. *International Journal of Science Education*. 21: 195–211.

Holistic Education Network. 2004. *Metacognition-Thinking About Thinking - Learning to Learn.* Holistic Education Network Tasmania, Australia.

Jager, B., Jansen, M., & Reezigt, G. 2005. The Development of Metacognition in Primary School Learning Environments. *School Effectiveness and School improvement*. 16: 179–196.

Kaberman, Z. & Dori, Y. J. 2009. Metacognition in Chemical Education: Question Posing in the Case-based Computerized Learning Environment. *Instructional Science*. 37: 403–436.

Kilpatrick, J. 1987. Problem formulating: Where Do Good Problems Come From? In A. H. Schoenfeld (Ed), *Cognitive Science and Mathematics Education*. Hilsdale, NJ: Lawrence Erlbaum. 123–147.

Kramarski, B., and Zoldan, S. 2008. Using Errors as Springboards for Enhancing Mathematical Reasoning with Three Metacognitive Approaches. *Journal of Educational Research*. 102: 137–151.

Krutetskii,V. A. 1976. *The Psychology of Mathematical Abilities in School Children*. (J. Teller, trans. & J. Kilpatrick & I. Wirszup, Eds.). Chicago: University of Chicago Press.

Kwakwa, A. 2012. *Teachers Asked to Adopt Problem Posing*. GNA. http;//ghananewsagency.devonet.com/details/education/teachers-asked-to-adopt-problem-posing-approach/?ci=9&ai=36707.

Lai, R. E. 2011. Metacognition: A Literature Review. *Research Report*. TMRS Staff.

Lave, J. 1988. *Cognition in Practice: Mind, Mathematics, and Culture in Everyday Life*. Cambridge, England: Cambridge University Press.

Leung, S. S., & Silver, E. A. 1997. The Role of Task Format, Mathematics Knowledge, and Creative Thinking on the Arithmetic Problem Posing of Prospective Elementary School Teachers. *Mathematics Education Research Journal*. 9(1): 5–24.

Lin, p. 2004. Supporting Teachers on Designing Problem-Posing Tasks as a Tool of Assessment to Understand Students' Mathematical Learning. *PME* 28, Bergen, Norway, July 14–18.

Lipman, M. 1985. Thinking Skills Fostered by Philosophy for Children. In, Segal, J. W., Chipman, S. F. & Glaser, R. (Eds.). *Thinking and Learning Skills: Volume 1: Relating Instruction To Research.* London; Lawrence Erlbaum Associates.

Matanzo, J. B. & Harris, D. L. 1999. *Encouraging Metacognitive Awareness in Pre-Service Literacy Courses: Advancing the World of Literacy.* Florida: Florida Atlantic University.

Nelson, T. 2012. *The Effectiveness of Metacognitive Strategies on 8th Grade Students In Mathematical Achievements and Problem Solving Skills*. Doctoral Dissertation. Faculty of the Graduate School. Southern University and A&M College.

Nelson, T. O., & Narens, L. 1990. Metamemory: A Theoretical Framework And New Findings. *The Psychology of Learning and Motivation*. 26: 125–141.

O'Malley, J. M., Chamot, A. U., Stewner-Manzanares, G., Russo, R. P., and Kupper, L. 1985. Learning Strategy Applications with Students of English as a Second Language. *TESOL Quarterly*. 19(3): 557–584.

Paris, S. G., & Paris, A. H. 2001. Classroom Applications of Research on Self-Regulated Learning. *Educational Psychologist*. 36(2): 89–101.

Patton, M. Q. 1990. *Qualitative Research and Evaluation Methods*. 2nd ed. Newbury Park, CA: Sage.

Patton, M. Q. 2002. *Qualitative Research and Evaluation Methods*. Thousand Oaks, CA: Sage.

Roth, W. M. & McGinn, M. K. 1997. Graphing: Cognitive Ability or Practice? Science Education. 81: 91–106.

Schoenfeld, A. H. 1985. *Mathematical Problem Solving*. San Diego: Academic Press.

Schoenfeld, A. H. Teaching Mathematical Thinking and Problem Solving. In L. B. Resnick and L. Klopfer (Eds.). *Toward the Thinking Curriculum: Current Cognitive Research (1989 Yearbook of the Association for Supervision and Curriculum Development)*. Washington, DC: Association for Supervision and Curriculum Development 1989. 83–103.

Schoenfeld, A. H. 1992. Learning to Think Mathematically: Problem Solving, Metacognition, and Sense Making in Mathematics. In D. A. Grouws (Ed.). Handbook of Research on Mathematics Teaching and Learning. New York, NY: Macmillan Publishing.

Schraw, G., Crippen, K. J., & Hartley, K. 2006. Promoting Self-regulation in Science Education: Metacognition as Part of a Broader Perspective in Learning. *Research in Science Education*. 36(1–2): 111–139.

Schunk, D. H. & Zimmerman, B. J. 1997. Social Origins of Self-regulatory Competence. *Educational Psychologist.* 32: 195–208.

Semadeni, W. 1986. Verbal Problems in Arithmetic Teaching. Proceedings of the International Congress of Mathematicians Berkeley, California, USA.

Silver, Edward, A., Down, J. M., Leung, S. S., and Kenny, P. A. 1996. Posing Mathematical Problems: An Exploratory Study. *Journal for Research in Mathematics Education*. 27(3): 293–309.

Singer, F. M., Ellerton, N., & Cai, J. F. 2013. Problem-Posing Research in Mathematics Education: New Questions and Directions. *Educational Studies in Mathematics.* 83(1): 1–7. doi: DOI 10.1007/s10649-013-9478-2.

Stickles, P. R. 2006. An Analysis of Secondary and Middle School Teachers' Mathematical Problem Posing. Doctoral Dissertation. University of Indiana.

Stillman, G. A., & Galbraith, P. L. 1998. Applying Mathematics with Real World Connections: Metacognitive Characteristics Of Secondary Students. *Educational Studies in Mathematics.* 36: 157–195.

Swanson, H. L. 1990. Influence of Metacognitive Knowledge and Aptitude on Problem Solving. *Journal of Educational Psychology*. 82(2): 306–314.

Tobin, K., & Gallagher, J. J. 1987. What Happens in High School Science Classrooms? *Journal of Curriculum Studies.* 19: 549–560.

Toluk-Ucar, Z. 2009. Developing Preservice Techers Understanding of Fractions Through Problem Posing. *Teacher and Teacher Education*. *25*: 166–75.

Zimmerman, B. J., & Bandura, A. 1994. Impact of Self-regulatory Influences on Writing Course Attainment. *American Educational Research Journal*. 31: 845–862.