Realizing Human Potential in The Emerging Era of Fourth Industrial Revolution: Collaborative Problem Solving Skills

Kamisah Osman

Faculty of Education, The National University of Malaysia
43600 Bangi, Selangor, Malaysia
Email: kamisah@ukm.edu.my

Abstract

The increasing pace of technological development and globalisation has changed the way we teach and how our students learn. As widely discussed in the literature of thinking and problem solving, collaborative problem solving skills has eventually expanded research on conventional problem solving skills. We are now witnessing the transition from manufacturing into a greater emphasis on services which are more information and knowledge-based, which has culminated in wider necessity of networked computers. Individuals are expected to and should be encouraged to work with diverse teams using collaborative technology. A closer look at inculcating collaborative problem solving skills reveals that it facilitates both the division of manpower and the integration of information from various sources of knowledge, perspectives and experiences. Such being the case, creative problem solving skills may equally enhance the creativity and quality of solutions created by means of effective teamwork. This presentation will focus on collaborative problem solving skills framework and how it could be meaningfully integrated within the context of science teaching and learning process. Based on the framework and subsequent learning activities that will be discussed, we will have a clearer picture of how by immersing students in collaborative problem solving skills learning environment will not only improve their learning, but also enhance their social interaction, teamwork and digital literacies.

Introduction:

Problem solving skills is one of the important learning outcomes that need to be emphasized in science teaching and learning. The rationale of integrating problem solving skills throughout science curriculum has been equivocally justified and outlined in both Malaysian primary and secondary school science curriculum (Ministry of Education, 2006; Osman, 1995). In science subjects, the importance of problem solving is also manifested through inquiry-based teaching and learning processes. In many science learning experiences, students are given problems to be solved, which require them to use problem solving strategies and skills as well as other higher order thinking operations. Thus, throughout the science education literature, the term problem solving is as frequently used as the terms scientific method, scientific thinking, methods of intelligence, and inquiry skills. Even though there are some variants among these terms, they are reflecting to some portion of problems solving ability (Champagne & Klopfer, 1977).

Problem solving is an important skill which causes every country's school emphasise this skill in their educational programs. Most countries in the world, their educators and policy makers are concerned about the students' real life

ISBN: 978-602-73192-1-9

problem solving abilities and competencies (OECD, 2003, 2010). It is thus argued that in order to effectively participate in society and handling personal issues, problem solving skills is crucial for future learning (OECD 2003). Students learn through the process of information understanding, identifying the interrelationships of critical features, external representation construction or application, problem solving and solution evaluation, justification and communication (OECD, 2003). Problem solving skills are critical to achieve advance skill level in facing with a real life situation. (Klieme, 2004). Importantly, students will employ basic thinking and cognitive approaches in confronting challenges in life when they master the problem solving skills. (Lesh & Zawojewski, 2007).Through problem solving activities, students can enhance their thinking skills, test hypothesis and apply procedures, deepen their conceptual understanding and more importantly, involved with the entire learning system without any anxiety (Das & Das, 2013).

Analysis of related literature reveal that when an imbalance exist between the inherent concepts and the conceptual schema, problem is said to exist (Pizzini et al., 1989). The occurrence of this kind of imbalance, which motivates individuals to solve problems, is conceptualized as “cognitive dissonance”. The process of solving problems will require the combination of prior knowledge with a higher-order skill that will enable the problems to be solved (Gagne, 1970). Depending upon the degree of “cognitive dissonance” that has occurred, the process of solving problems may also require a stored information reorganization in order for a person to reach to a specific goal. However, the success of prior knowledge application to a problem is also related to the degree how person relate the problem with their prior knowledge meaningfully. (Bransford et al., 1986; Gagne, 1970; Kirschner 1992).

Problem Solving as Inquiry

Problem solving is an inquiry domain in which students are emphasize in the process of observation, classification, hypotheses formulation, variables identification and control, experimentation, and making valid conclusions (Gagne, 1970). A mode of inquiry involves necessarily the challenges of the status quo and a continuous reconceptualization of what is learned and how knowledge is constructed. As noted by Jaworski (2006), within an inquiry based community, students, through their critical reflectionwill contribute towards a continuous community reconstitution.

Thus, an integrating principle in all scientific problem-solving approaches is that questions posing regarding a particular problem and situations are a vital element that lead to important information recognisation. This in further will lead to meaning exploration associated with the concepts. These questions are not just relevant during the entire solution process; but it helps to extend the problem into other related problems. As argued by Postman and Weingartner (1969), by gathering relevant, appropriate and substantial questions an individual have learnt how to learn everything (Postman & Weingartner, 1969). This is because, throughout the processes, we constantly reflect on ways to articulate and apply our ideas (Carpenter & Lehrer, 1999).

In science teaching and learning, inquiry approach is a successful intervention technique due to its ability to facilitate scientific problem solving and let students inquire their own observations, construct hypotheses, and analyse the experimental data, (Shin et. al, 2003), test those hypotheses by experimentation, and evaluate evidence (Windschitl, 2000). Besides navigating students' conceptual understanding, Adesoji (2008) emphasize that problem solving activities in science is of vital importance in order to create a positive attitude towards the subject. Students adopt a negative attitude towards things that they do not understand as well as the low self-confidence of the individual in relation to their problem solving skills. In a similar vein Adesoji (2008) also found that by allowing science students to develop higher cognitive processes through a teacher-directed or self-directed problem solving strategies will significantly improve their attitudes toward the subject. Therefore, it was then recommended that teachers should adopt problem solving strategies in their teaching. Besides, immersing students in problem solving learning activities will provide them opportunities to apply scientific concepts and principles which in turn develop more positive attitude toward science learning.

Problem Solving Learning Activities

In Malaysia, like in many other countries, students have a low level of science problem solving skills (Tambychik & Meerah, 2010). As shown in many studies, the biggest obstacle in Mathematics problem solving is due to lack of computational and mathematics skills. Studies showed that most problem-solving process require mathematics skills application. However, large numbers of students have not acquired the basic skills they need in mathematics problem solving (Mohd Nizam & Rosaznisham 2004), resulting in difficulties in mathematics problem solving (Tay 2005; Tambychik 2005). Tambychik and Meerah's (2010) study also revealed that the incompetency in mathematics skills acquisition and lack of cognitive abilities are the cause of the students' mathematic problem solving difficulties. Besides, the most critical mathematics skills is the information skill. Without information skill mastering, they will not understand and make meaningful interelationships between the information. Furthermore, lack language skill, information skill and numbering skill inhibits problem solving efficiency. As a result, it would lead to errors in mathematical problem-solving (Tambychik & Meerah 2010). Garderen (2006) also stated that deficiency in visual-spatial skill might cause difficulty in differentiating, relating and organizing information meaningfully.

In science, problem solving involves not just mathematical skills, but more importantly understanding the language used, the interpretation of the problem given and an understanding of the science concepts involved in the solution. Analysis of literature shows that the major reason of the students' unability to solve problems in science is that they do not understand the concepts of the problems. The comparison of the procedures used in problem solving between the inexperience students and the experts show that experts were able to retrieve relevant concepts more readily from their long term memory. It was found that experts' concepts are linked to one another. In addition to that, unlike the novices, the experts plan the dtrategies to be used prior to the procedure. In the past few years, problem solving research in science education have recorded a high number of high school students that do not understand the meaning of many basic scientific concepts such as mass, volume, heat, temperature and changes of state. Furthermore, reading difficulties are also found as factor affecting science problem solving among students. This difficulties are classified by Phonapichat et al. (2014) and Uthai (1998) as:

i) Students cannot understand the whole or some parts of the problem due to the lack of imagination and experience needed to consider the problem;
ii) Students have difficulties in reading and comprehension, unable to understand what important information is in a problem and organize it accordingly. Thus they cannot invert the text into mathematical symbols;
iii) Students' lack of interest in solving problems due to the length and complexity of the problems, which is demotivating;
iv) Teachers do not present daily life matters as problems very often;
v) Teachers are likely to make students memorize "keywords" in the problems to use in formulae;
vi) Teachers focus on following examples given in textbooks rather than teaching the principles behind each problem;
vii) Teachers teach without concern with thinking process orders

This is why Pizzini et.al. (1988) suggest that: "if we are to enhance the development of thinking skills, we must place greater emphasis on applying the application of learning to real life problem. In other words, we must emphasize the levels of thinking known as "processing" and "output", rather than the level of thinking known as "input"." This concept of applying the application of learning to real problems is supported by others involved in the field (e.g. Costa & Lowery 1989; Mayer 1990). Thus, the best approach to enhance thinking and problem solving skills is by giving the students the opportunity to investigate; viz, provide access for them to learn by *"sciencing"* (McNairy 1985). However, scientists do not begin their science operations in the laboratory. They often start with establish the problem, and subsequently turn to other processes for verification in his laboratory. Nordin and Hassan (1993) claim that scientists undergo two different phases in their thinking, namely *"problem seeking"* and *"problem solving"* phases. Thus, in addition to "sciencing" activities, *"processing"* and *"output"* activities should be emphasized rather than merely bombarding students with "input" information.

The easiest way to understand the *"process"* and *"output"* activities is to consider some typical questions related to each of them. For instance, *"Which of these animals are reptile?"* and *"List the factors that affect the rate of chemical reaction"* are typical input level questions. These type of questions only involve a skill of recognition and recall *(knowledge level)*. However, *"How the molecular structure of liquid is different from that of a solid"* and *"What can you infer about the role of bacteria from a carbon cycle"* are processing level questions. That is, it require the application of students' acquired knowledge and comprehension to a specific situation *(comprehension and application)* and to break down an idea into parts as well as identifying interrelationship of these parts *(analysis).* Two examples of output level questions might be "What is the best way to prevent people from smoking?" and *"What will happen to its molecular structure if we heat the liquid?"*. In this case, the questions lead the students to make judgments about the values of information available (evaluation) and also to put together elements that form something original (synthesis). The presentation of output level questions to the students will require them to go beyond the circle of data at hand and use of the data in new ways such as hypothesizing, generalizing, and evaluating. Such view is also consistent with that of Costa and Lowery (1989) who suggest that students can be initiated to think creatively effectively by carefully presenting them to syntax of questions and statements that encourage processing and output mental activities. It should also be noted that successful teaching of problem solving require more than just appropriate teachers' questioning techniques as mentioned earlier. It requires a "thoughtful classroom" to bring about effective problem solving outcomes. Such a classroom is conceptualized as one where "…the goal is to engage students in a challenging problems, guide them to manipulate the information, and support their effort". Table 1 summarizes the "minimal criteria for classroom thoughtfulness. Based on Table 1, teachers have responsibility for controlling the classroom climate in which teaching will take place as well as appropriate lesson planning. He or she can begin to accomplish this, for example by providing students enough "wait time" (Rowe 1974) and changing the physical arrangement of the classroom for more conducive interaction among the students and teacher.

Table 1. The Minimal Criteria for Classroom Thoughtfulness

Source	Characteristics of behavior
General	• There is general sustained examination of a few topics rather than superficial coverage of many • The lesson displays substantive coherence and continuity • Students are given time to think, that is, to prepare responses to questions • The teacher asked challenging questions and or structured challenging tasks
Teacher	• The teacher was a model of thoughtfulness (e.g. Showing interest in students' ideas, and in alternate approaches to problem, showing how he/she thought through a problem, and acknowledging the difficulty of gaining a definitive understanding of problematic topics)
Student	• Students offered explanations and reasons for their conclusions

Conceptualization of Problem Solving Skills

Problem solving is a cognitive process involve in transforming a given situation into a goal situation (Mayer 1990). Mayer (1992) further emphasised that the assessment designer of problem solving must require the problem solver to engage in higher-order thinking, skills integration, and face a non-routine problems by inventing a novel strategy. A review of the related literature reveals that there is a wide spectrum of problem solving models that can be used as a frame of reference by teachers in the processes of delivering scientific and mathematical concepts (Bransford et al. 1986; Pizzini et al. 1989; Butler 1993). One of the most commonly used problem solving models included the early version of Polya (1957), namely the Four Stages Model of Problem Solving. The model was further revised into three stages in 1974. Table 2 shows a variety of cognitive processes that underpinned different problem solving models in literature. As contended by Kirschner (1992), regardless of how problem solving is conceptualized, superficially all problem-solving models will involve: i) problem conception, ii) problem definition, iii) generation of alternative solution strategies, iv) specification of a strategy, v) problem solution, and vi) evaluation of solution.

Table 2. Problem Solving Models

Authors	Year	Cognitive Process
Bloom, Hastings, & Madaus	1971	Knowledge, comprehension, application, analysis, synthesis, and evaluation
Polya	1974	Understand the problem, explore the problem and develop a plan
Hannah & Michaelis	1977	Interpreting, comparing, classifying, gneralising, inferring, analysing, synthesising, hypothesising, predicting, and evaluating
Miller, Williams & Haladyna	1978	Summarising, predicting, evaluating, applying
Polya	1981	Understanding problem,planning, performing the plan, confirmation of the answer;
Biggs & Collis	1982	Unistructural, multistructural, relational, extended abstract
Pizzini et al.	1988	Identify, Define, Explore, Act and Look
Klahr & Dunbar,	1988	Search in the hypothesis, Testing hypotheses, Evaluating evidence
Pizzini et al.	1989	Search, Solve, Create and Share
Krulick & Rudnick	1996	Reading and thinking, analyze and planning, organizing strategy, getting the answer, confirmation of the answer.
Zalina	2005	Understanding problem, solving the problem, stating the answer
Koppelt	2011	Understanding & Characterizing the problem, Representing the problem, Solving the problem, Reflecting & Communicating the solution

However, discussion in this presentation will be based on OECD (2003, 2010) definition of problem solving skills. According to OECD (2003, 2010), problem solving competencies refer to:
“Individual’s capacity to use cognitive processes to confront and resolve real, cross-disciplinary situations where the solution path is not immediately obvious and where the literacy domains or curricular areas that might be applicable are not within a single domain of mathematics, science or reading” OECD (2003, p. 156)
“ students’ abilities to create and monitor a number of processes within a certain range of tasks and situations. OECD (2010, p.12) defined problem solving competency is an individual’s capacity to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious. It includes the willingness to engage with such situations in order to achieve one’s potential as a constructive an reflective citizen” OECD (2010, p.159)

Based on the above definition, it could be synthesised that both OECD (2003) and (2010) definitions of problem solving emphasized the cognitive processes, and the cross-curricular or multidisciplinary nature of problem solving skills assessment. In the 2003 definition, cross disciplinary refers to extending the consideration of student competencies to a wider range of problem solving items falling across the boundaries of curricular areas, including mathematics, science, literature, social studies, technology and commerce. Meanwhile, cognitive process refers to the application of understanding, characterizing, representing, solving the problem, reflecting the solution and communicating the problem solution (OECD, 2003). Details of each problem solving process are presented in Table 3.

Table 3. Problem Solving Cognitive Process and its Operationalisation

No.	Cognitive Process	Operationalisation
1	Understanding the problem	How students understand a text, a diagram, a formulae or a table and draw inferences from it; relate information from various sources; demonstrate understanding of relevant concepts; and use information from their background knowledge to understand the information given.
2.	Characterising the problem	How students identify the variables in the problem and their interrelationships; decide which variables are relevant and irrelevant; construct hypotheses; and retrieve, organise, consider and critically evaluate contextual information.
3.	Representing the problem	How students construct tabular, graphical, symbolic or verbal representations, or how they apply a given external representation to the solution of the problem; and how they shift between representational formats.
4.	Solving the problem	Making decision; analysing a system or designing a system to meet certain goals, or diagnosing and proposing a solution
5.	Reflecting the solution	How students examine their solutions and look for additional information or clarification; evaluate their solutions from different perspectives in an attempt to restructure the solutions and make them more socially or technically acceptable; and justify their solutions.
6.	Communicating the problem solution	How students select appropriate media and representations to express and communicate their solutions to an outside audience.

From Individual to Collaborative Problem Solving Skills

Collaborative Problem Solving (CPS) skills have over the years been considered as critical and necessary across various educational contexts and workforce. More importantly, a growing interest has been observed in CPS skills in the 21st century. A closer look at inculcating CPS skills reveals that it facilitates both the division of labour and the integration of information from various sources of knowledge, perspectives and experiences. Additionally, CPS skills may equally enhance the creativity and quality of solutions created by means of effective teamwork. Just like problem solving, the collaborative problem solving framework is based on the one propagated by the OECD. Such a paradigm transition from PS to CPS is a result of scholars' disposition towards exploring collaboration owing to its distinct advantages over individual PS. In addition, related previous studies have revealed that the PS skills paradigm may limit the capacities of individuals who work alone to resolve problems. It was also found that in individual PS, the method of solution was not immediately obvious to the individual engaged in the PS task (OECD, 2010).

It was owing to such drawback that the OECD has alternatively considered CPS (OECD, 2013). In this regard, the defined CPS as the capacity of an individual to effectively engage in a process, in which two or more agents (i.e. human beings or computer-simulated participants) attempt to solve a problem by both shared understanding and efforts required to find a solution. More specifically, such a process may involve pooling their knowledge, skills and efforts to reach such a solution.

As presented in Table 4, there are three major CPS competencies which are crossed with the four-major individual PS processes from the PISA 2012 PS framework (OECD, 2010)to form a matrix of specific skills for CPS framework (OECD, 2013) .The specific skills have associated actions, processes, and strategies that define what it means for the student to be competent

Table 4: Matrix of CPS framework

		CPS competencies		
		(1) Establishing and maintaining shared understanding	(2) Taking appropriate action to solve the problem	(3) Establishing and maintaining team organisation
	(A) Exploring Understanding	(A1) Discovering perspectives and abilities of team members	(A2) Discovering the type of collaborative interaction to solve the problem, along with goals	(A3) Understanding roles to solve problem
	(B) Representing	(B1) Discovering	(B2) Identifying	(B3) Describe

Problem solving skills	and Formulating	perspectives and abilities of team members	and describing tasks to be completed	roles and team organisation (communication protocol/rules of engagement)
	(C) Planning and Executing	(C1) Communicating with team members about the actions to be/being performed	(C2) Enacting plans	(C3) Following rules of engagement, (e.g., prompting other team members to perform their tasks.)
	(D) Monitoring and Reflecting	(D1) Monitoring and repairing the shared understanding	(D2) Monitoring results of actions and evaluating success in solving the problem	(D3) Monitoring, providing feedback and adapting the team organisation and roles

Note: The 12 skill cells have been labelled with a letter-number combination referring to the rows and columns for ease of cross- referencing later in the document (OECD, 2013)

In line with such a definition, the infusion of CPS skills among communities of learners may help overcome the present PS work challenges. It is worth highlighting that the transition from manufacturing to a service economy which is more information and knowledge-based has culminated in wider availability of networked computers. In such a scenario, individuals are expected to work with diverse teams using collaborative technology. Considering the level of transformation as discussed in the foregoing paragraphs, there is a growing need for CPS skills in civic contexts such as social networking, volunteering, and participation in communal activities, transactions, administration and public services. In this regard, students upon leaving schools and stepping into the workforce and public life may have to equip themselves with CPS skills as well as the ability to engage in such a collaboration using appropriate technology. In addition, it is believed that the inculcation of CPS skills not only develop individual PS skills among students, but also enhance their social interaction, teamwork and ICT literacy in the course of the PS learning process (OECD, 2013).

Conclusion

In particular, discussion in this paper argues that the science curriculum is in a unique position to take up challenge of creating in children those thinking and problem solving skills which will be essential in this 21st century. The problem solving models and frameworks synthesized and discussed could be used as guidelines in nurturing as well as evaluating problem solving capacities among our future generation.New demand in the workplace especially in the next five to ten years require students' to be able to work collaboratively and solve complex as well as multidisciplinary problems. Thus, framework as discussed in this presentation could be used as guideline in crafting collaborative problem solving activities in science classroom. However, it should be noted, the teaching as well as assessment of collaborative problem solving skills in science teaching and learning is not as easy as might have beenconceptualized by many. Are our science teachers willing to use the current approach of collaborative problem solving activities as one of their classroom activities? And what about the students, do they have all the pre-requisites to fully participate in such kind of learning activities and assessment mechanisms if it is implemented in their science classroom?

References

Adesoji, F. A. (2008). Managing students' attitude towards science through problem–solving instructional strategy. *Anthropologist*, *10*(1), 21-24.

Bransford, J., Sherwood, R., Vye, N., & Rieser, J. (1986). Teaching thinking and problem solving: Research foundations. *American psychologist*, *41*(10), 1078-1089

Butler, J. (1993). *Thinking Skills In Human Development: At School And At Work*. Paper Presented at the International Convention on excellence in thinking. National University Of Malaysia, Malaysia.

Carpenter, T. P., & Leherer, R. (1999). Teaching and learning mathematics with understanding. In: E. Fennema, & T. A. Romberg (Eds.), *Mathematics classroom that promote understanding* (pp. 19–42). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Champagne, A. B. & Klopfer, L. E. (1977). A Sixty Year Perspectives on Three Issues in Science Education. *Science Education*, *61*(4), 431-452.

Costa, A. L. & Lowery, L. F. (1989). *Techniques for teaching thinking*. California: Howest Publication

Das, R., & Das, G. C. (2013). Math anxiety: The poor problem solving factor in school mathematics. *International Journal of Scientific and Research Publications*, *3*(4), 1-5.

Gagne, R. M. (1970). *The conditions of learning (2nd Ed.)*. New York: Holt, Rinehart, & Winston.

Garderen, D. V. (2006). Spatial Visualization, Visual Imaginary and Mathematical Problem Solving of Students with Varying Abilities. *Journal of Learning Disabilities, 39*(6), 496– 506.

Jaworski, B. (2006). Theory and practice in mathematics teaching development: critical inquiry as a mode of learning in teaching. *Journal of Mathematics Teacher Education, 9*(2), 187–211.

Kirschner, P. A. (1992). Epistemology, Practical Work and Academic Skills in Science Education. *Science and Education,1*, 273-299.

Klieme, E. (2004). Assessment of cross-curricular problem-solving competencies. In J. H. Moskowitz & M. Stephen (Eds.). *Comparing learning outcomes.*

International Assessments and Education Policy (pp.81-107). London: Routledge.

L. H., Tay (2005). *Problem solving abilities and strategies in solving multistep mathematical problems among Form 2 students*. Kertas Projek Sarjana. Universiti Malaya.

Lesh, R. & Zawojewski, J. S. (2007). Problem solving and modeling. In F. Lester (Ed.). *The Second Handbook of Research on Mathematics Teaching and Learning.* (pp. 763-804). Charlotte, NC: Information Age Publishing.

Mayer, R. E. (1990). Problem solving. In M. W. Eysenck (Ed.), *The Blackwell dictionary of cognitive psychology*. Oxford, England: Blackwell.

Mayer, R. E. (1992). *Thinking, Problem solving. Cognition* (2nd Ed.). New York, NY: Freeman

McNairy, M.R. (1985). Sciencing: Science education for early childhood. *School, Science and Mathematics, 85*(5), 383 - 393.

Ministry of Education Malaysia (MOE) (2005). *Integrated curriculum for secondary school: Curriculum specification Mathematics Form 4*. Putrajaya: Curriculum Development Centre

Mohd Nizam Ali & Rosaznisham Desa (2004). Meningkatkan Kemahiran Mengingat Sifir 3,6 dan 9 di Kalangan Murid Pemulihan Tahap 2. *Jurnal Kajian Tindakan Pelajar PSPK. Kementerian Pendidikan Malaysia*, 102 – 112

Nordin, A.B. & Hasan , S. (1993). *Innovative thinking among scientists in Malaysian context*. Paper presented at the International Convention of Excellence Thinking. The National University of Malaysia. Malaysia.

OECD (2003) The PISA 2003 *Assessment Framework: Mathematics, Reading, Science and Problem Solving Knowledge and Skills*.

OECD. (2010). *PISA 2012 field trial problem solving framework. Draft subject to possible revision after the field trial. Paris, France: OECD*. Retrieved from http://www.pisa. oecd.org/dataoecd/8/42/46962005.pdf

OECD. (2013). *PISA 2015 Draft Collaborative Problem Solving Framework*. Retrieved from https://www.oecd.org/pisa/pisaproducts/Draft PISA 2015 Collaborative Problem Solving Framework .pdf

Osman, K. (1995). *Constructing a Malaysian Science Curriculum: Retaining Tradition in a Context of Change*. Unpublished Master Dissertation. The University of Manchester.

Phonapichat, P., Wongwanich, S., & Sujiva, S. (2014). An analysis of elementary school students' difficulties in mathematical problem solving. *Procedia-Social and Behavioral Sciences*, *116*, 3169-3174.

Pizzini et al. (1989). A rationale for and the development of a problem solving model of instruction in science education. *Science Education,73* (5), 532-534.

Polya, G. (1957). *How to Solve lt*. Princeton: Princeton University Press

Postman, N., & Weingartner, C. (1969). *Teaching as a subversive activity*. New York: A Delta Book.

Rowe, M.B. (1974). Wait time and rewards as instructional variables: Their influence on language, logic and fate control. *Journal of Research in Science Teaching*, *11*(20, 81-94.

Shin, N., Jonassen, D. H., & McGee, S. (2003). Predictors of well-structured and ill-structured problem solving in an astronomy simulation. *Journal of Research in Science Teaching*, *40*(1), 6-33

Tambychik, T (2005). *Penggunaan Kaedah Nemonik Berirama dalam Pembelajaran Matematik bagi Pelajar Lemah: Satu Kajian kes*. Tesis Sarjana. Universiti Kebangsaan Malaysia.

Tambychik, T., & Meerah, T. S. M. (2010). Students' difficulties in mathematics problem-solving: what do they say? *Procedia-Social and Behavioral Sciences*, *8*, 142-151.

Uthai, P. (1998). *Teaching mathematical problems by four questions*. Ministry of Education.

Windschitl, M. (2000). Supporting the development of science inquiry skills with special classes of software. *Educational Technology Research and Development*, *48*(2), 81-95