COGNITIVE PROCESSES IN SOLVING THE ILL-STRUCTURED PROBLEMS OF MANAGEMENT SCIENCE OF MALAYSIAN UNDERGRADUATE BUSINESS DEGREE STUDENTS

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Abstract

Problem solving is regarded by many educators as the most meaningful and important way of learning and thinking. The ability to aptly apply cognitive skills in problem solving is considered as the fundamental and crucial aspect in a human life. Problems are generally classified and represented by a continuum from well-structured to ill-structured (IS). Both well- and ill-structured problems are different in nature. Well-structured problems are often used in classroom while the ill-structured problems are normally confronted in the real world. Many studies have indicated that Malaysian graduates do not possess the required problem solving skills to meet the societal and industrial demands, especially with the increase in complexity of problems in this millennium. This study explored the cognitive processes and pathways used by Malaysian undergraduate business degree students (UBD) in solving ill-structured (IS) MS problems. The crux of Management Science (MS) is to equip students in problem solving skills during their formal education. A sample 42 UBD students from six tertiary institutions were selected for this case study. Obtrusive observations and in-depth interviews were conducted as techniques for data collection. The cognitive processes were determined from behaviour and performance exhibited by participants while they were delineating the concepts, propositions and strategies in their solution paths. The problem solving sessions using the 'think aloud' approach were audio- and video-recorded. All written responses and transcripts of video-recordings and interviews in the problem solving sessions were transcribed, analysed, triangulated and classified into episodes of strategies for the interpretations of the cognitive processes. The findings from this study reveal that non-linear pattern of cognitive processes was evident. The pathway to solving the problem had influenced the individual's decision-making outcomes. However, there were similarities and differences in cognitive processes between successful and unsuccessful solvers. The study suggests significant implications for the development of effective MS pedagogies and improvements in the design of instructional materials. It is anticipated that problem solving skills of UBD could be enhanced through the learning ability in solving the MS ill-structured problem during their formal education, henceforth, meeting the challenges of societal and industrial demands and expectations.

Keywords: Cognitive processes, ill-structured problems, problem solving, management science

1. INTRODUCTION

Problem solving is regarded by many educators as the most meaningful and important way of learning and thinking. It is also regarded as one of the educational objectives in the international education system (OECD, 2004). However, in Malaysia, studies (Ab Rashid, Hussin, & Putih, 2005; HRDF, 2011, PISA, 2012; PISA, 2014) periodically reported that fresh graduates generally lacked problem solving skills when they started on their careers. Problem solving skill is one of the critical skills sought-after by the employers. Although there was a general agreement among educators that problem solving skills of students have to be improved, much emphasis was put on examination results. The development of creativity in students' problem solving skills has been side-lined.

The consecutive years of poor performance in The Programme for International Student Assessment (PISA) on creative problem-solving has jolted an alarm in the country and a widespread of public concerns on the Malaysia's education system. Dr Frederico Gil Sander, World Bank senior economist has pointed out that the poor quality of Malaysia's education system was more worrying than the debt level of its households (Zachariah, 2014). Elsewhere, Andreas Schleicher, Acting Director of Education and Skills at OECD also commented that "Today's 15-year-olds with poor problem-solving skills will become tomorrow's adults struggling to find or keep a good job. Policymakers and educators should reshape their school systems and curricula to help students develop their problem-solving skills which are increasingly needed in today's economies." (Zachariah, 2014, para 12). Funke (2013, p.2) also emphasized that: "(Our) society is in urgent need for new insight about the way human deals with complexity and uncertainty." Thus, the reiteration that acquisition of problem solving skills during their formal education still have much room to be researched and improved globally, especially among Malaysian students, specifically among undergraduate students who would soon be the future decision makers in the society.

Problem solving skills are not inborn but something that could be learned and taught (Polya, 1957). According to Renki & Atkinson (2003), problem solving is considered as the superior cognitive skill acquisition. Without understanding the thinking processes of students in solving problems, it would be difficult to teach students how to improve their problem solving skills. To improve the problem solving skills of students during their formal education has been included in the Malaysia Education Blueprint 2013-2025 as one of its important agenda (The Star, 2/4/2014).

The discipline of MS came into existence due to the need to solve problems. Moreover, most of MS problems are real world problems but complex in nature. Studies reported that Management Science methods have been increasingly used for tactical, operational and organizational decision making in Malaysia and many other Asian countries (Chang & Hsieh, 2008; Munisamy, 2012). The current undergraduates, especially business students are the future leaders of Malaysia as they are expected to have effective decision making and problem solving skills in the corporate world. Thus, the development of problem solving skills could be paramount for students during their formal education. Towards this end, it is logical to assume that by improving the skills in solving MS problems, it could help students to improve their problem solving skills in real life problems. It is the purpose of this paper to present part of the findings of a study that has investigated the cognitive processes of undergraduate students in solving MS problems.

MS problems could be generally classified into three kinds namely puzzle problems, well-structured (WS) problems and ill-structured (IS) problems. According to Jonassen, well-structured problems are "constrained problems with convergent solution that engage the application of a limited number of rules and principles within well-defined parameters. Ill-structured (IS) problems possess multiple solutions, solution paths, fewer parameters which are less manipulable and contain uncertainty about which concepts, rules and principles are necessary for the solution or how they are organised and which solution is best." (Jonassen, 1997, p.65). However, the problem types did not represent a well-defined classification, they represented a continuum from well-structured to ill-structured problems (Jonassen, 1997). While problem solving provides an opportunity for meaningful learning, different types of problems play different roles in learning (Ching, 2009). In the context of the research in investigating the problem solving skills of undergraduates ready for employment, ill-structured Management Science (IS-MS) problem was selected. The cognitive processes in solving IS-MS problems were the focus of the investigation. Henceforth, the main aims of this study were: (a) to investigate the cognitive processes of UBD students in solving the IS-MS problem, (b) to explore any similarities and/or differences of cognitive processes in successful solvers and unsuccessful solvers, (c) to identify any relationship between strategies employed in successful solvers and unsuccessful solvers.

2. REVIEW OF RELATED LITERATURE

Cognitive processes in problem solving is one of the fundamental human cognitive processes (Wang & Chiew, 2010), which refers to human thinking and information processing (Polya, 1957; Newell & Simon, 1972). According to Ormrod (2008), cognitive processes can be defined as a particular way of mentally responding to or thinking about information or an event, and problem solving was to use existing knowledge and skills to address an unanswered question or troubling situation. Guided by this concept, cognitive processes in problem solving can be operationalised as the thinking processes and recalling of existing knowledge and skills to resolve a problem.

MS is a scientific approach to problem solving and decision making. It encompasses logical and wide range approaches to problem solving. The field of MS was born entirely for the purpose of solving real problems (Jensen, 1999). In the context of MS, problem solving was defined as “the cognitive processes of identifying differences between the actual and the desired state of affairs and then taking action to resolve the difference” (Rosenhead, 2001, p.15). It applies scientific and systematic procedures, techniques and tools to operational, strategic and policy problems to help develop and evaluate solutions to problems encountered within management. It had been acknowledged by the industries as an efficient managerial tool for economic development (Chang & Hsieh, 2008). It includes all rational approaches to management decision-making (Beasley, 2011). MS problems make a person think, as espoused by Beasley (2011, p. 13), “Even if you never do anything with the mathematics, this (formulation) process of trying to think clearly and logically about a problem can be very valuable.” Through using analytical and numerical techniques, MS professionals solved complex problems and improve system performance (INFORMS, 2013).

There are many different types of problems faced by humans requiring solutions. They can be described and classified based on the domain, the nature of the problem, the problem situation, the processes and the solution (Jonassen, 1997; Reitmen, 1965; Newell & Simon, 1972). The domain, goal and processes may result in a problem that is considered very well-structured or very ill-structured (Jonassen, 1997). The problem domain defines the problem elements according to its concepts, rules and principles. The nature of the problem described the combination of concepts, rules and procedures to solve the problem. The problem solver's understanding and representation of the problem type defined the problem-solving process. The solution to the problem was referred as the goal, which might be convergent or divergent. Jonassen (1997) commented that the solution to the problem was one of the critical attributes of problem solving. It was not always explicit or specified in the problem statement. The problem solver must identify not only the nature of the problem but also an acceptable solution, and a process for arriving at it.

In real life, the domain of the problems ranges from highly structured to ill-structured (Newell & Simon, 1972). However, Simon (1973) asserted that there is no real boundary between well-structured (WS) problems and ill-structured (IS) problems. The boundary between a well-defined and ill-defined problem is very vague, fluid and not susceptible to formalization. Many kinds of problems often treated as WS are better regarded as ill-structured.

Ill-structured (IS) problems, on the other hand, are problems that in their problem nature does not give any particular hint on the pattern of approach, and there is no convergent solution. These problems possess multiple solutions, solution paths, fewer parameters and are less manipulable, and contain uncertainty about which concepts, rules and principles are necessary for the solution or how they are organised (Jonassen, 1997). Many studies (Chi & Glaser, 1985; Schraw et al, 1995; Voss,1988; Wood,1983) characterised the IS problem as one that the problem situation is not well specified, the problem descriptions are not clear or well-defined, and information needs to solve them are not contained in the problem statement. IS problems are problems we encountered in our daily practice. They are not content constrained and solutions are not predictable. Sometimes, they might require integration of several content domains (Jonassen, 1997).

In sum, IS problems do not provide sufficient information on goals, constraints and criteria to solve the problem and evaluate the solution. In addition, this type of problem has multiple solutions and multiple solution paths to obtain the solution (Ching, 2009).

3. THE METHODOLOGY AND MODEL

In order, to investigate and examine the cognitive processes of the UBD students while they are solving a IS-MS problem, a qualitative approach with a focus on phenomenography was adopted.
A purposive sample of 42 which comprised 20 male (47.62%) and 22 female (52.38%) willing participants were selected from those who enrolled in the Business degree programme from six different Universities/Colleges in the Klang Valley, Malaysia.

Participants were introduced to use the “think aloud” method during the problem solving session. The entire problem solving session of each participant was video- and audio-recorded and time was also recorded accordingly. Data were then collected in the following four steps. Individual participant was firstly introduced to the “think aloud” method and technique, followed by a short discussion to clarify and confirmed if he/she understood the meaning of “think-aloud” method. Secondly, the participant was interviewed with the structured questions to find out the education background and their degree of exposure to the MS problems. Thirdly, participant was given the IS-MS problem with a brief explanation on the problem, freedom to use whatever method(s) deemed suitable to solve the problem was emphasized. Fourthly, participant was interviewed with a set of semi-structured questions, in retrospect, upon completion of his/her work on solving the given problem. By combining the researcher’s observations, field notes, participants’ works and verbatim, the data were triangulated for analysis.

An IS-MS question (Table 1) was adopted from Michael L Pinedo (2005, p.5) *Planning and Scheduling in Manufacturing and Service*. Based on the guidelines of problem structuring methods (or Soft OR) developed by Rosenhead (2001), it was adapted to reflect the emphasis on the importance of each individual’s perception of the situation. This IS-MS question has been subjected to validation.

Table 1 : Ill-structured Management Science Problem

You are the production manager in the ABC Paper Mill. You are responsible for the production output and quality of the paper. *The production planning in the paper mill goes like this:* *The input to a paper mill is wood fiber and pulp; the output is finished rolls of paper. At the heart of the paper mill are its paper machines, which are very large and represent a significant capital investment (between 50 and 100 million dollars each). Each machine produces various types of paper characterized by their basis of weights, grades and colours.* *Master production plans for these machines are typically drawn up on an annual basis. The projected schedules are cyclic with cycle times of two weeks or longer. A particular type of paper may be produced either every cycle, every other cycle, or even less often, depending upon the demand.* *Every time the machine switches over from one grade of paper to another, a setup cost is incurred. During the changeover the machine keeps on producing paper. However, since the paper produced during a changeover does not meet any of the set standards, it is either sold at a steep discount or considered waste and fed back into the production system.* *Determine what should be done to improve the production performance.*

To solve this IS-MS problem, participants were expected to demonstrate their cognitive processes by recalling their prior knowledge, as this is an applied, real-world related problem. There might be no one fixed or absolute solution, and multiple solutions be generated. To recall one’s prior knowledge, long-term memory (LTM), played an important role in assessing the participants’ cognitive processes in solving the problem. Although there was no restriction on which method should be used, participants were expected to solve the problem in a logical way, such as understanding the objective(s) of the problem, able to identify the issue(s) of the problem and make necessary assumptions based on the condition(s) of the problem.

4. RESULTS

A marking scheme with a total of 12 points was developed and validated. All written scripts were reviewed and marked. Fig.1 shows the score distribution of 42 participants.

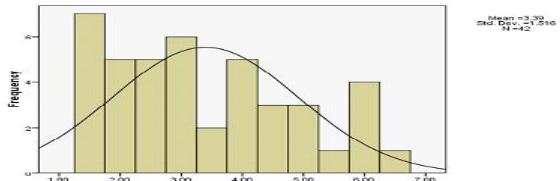


Fig.1: Distribution of Score of Participants Solving IS-MS Problem

A score of 4.5 points (≅ 40%) was adopted as a cut-off point. That is, if a script was awarded 4.5 points and above, it was considered as a successful attempt, otherwise it was considered as unsuccessful.

There were 29% (12) participants categorised as successful solvers (SS) and 71% (30) participants as unsuccessful solvers (US). Although there was no restriction on the methods to be used, participants applied their prior knowledge and experiences to solve the problem. A series of methods were used which included reviewing master production plan/monitor production plan, improving machinery to improve efficiency, improving cost control, monitoring cycle time, conducting proper planning, managing inventory control, implementing just-in-time (JIT), controlling quality, integrating with other producers, implementing marketing promotion, monitoring demand, recycling waste paper, improving management skills in the areas of costing & efficiency, improving labour performance through training, targeting lower income group to use the lower quality papers, monitoring raw materials (inputs), controlling system process, optimising work to achieve efficiency, stringent supervision, supply chain management, minimising waste, and recruiting more labourers. In short, they could be categorised into five areas namely: a) planning for production plan; b) monitor production process and monitor quality of inputs and outputs; c) monitor costing and efficiency; d) recruit and train personnel to meet the production demand; and e) others. Table 2 summaries the methods which participants adopted in solving the IS-MS problem.

Table 2: Summary of methods participants adopted in solving the IS-MS problem

		(SS)		(US)	
		Number	%	Number	%
Area	Methods	12	29%	30	71%
Planning for production plan	Review master production plan/monitor production plan	6	50%	7	23%
	Proper planning	3	25%	0	0%
	Integrate with other producers	1	8%	0	0%
Monitored production process and monitored quality of inputs and outputs	Inventory control	3	25%	3	10%
	Monitor cycle time	3	25%	6	20%
	Just-in-time (JIT)	2	17%	1	3%
	Quality control	2	17%	7	23%
	Monitor inputs	0	0%	3	10%
	Monitor production process / reduce changeover time	0	0%	17	57%
	Control system process	0	0%	1	3%
Monitored costing and efficiency	Improve machinery / investment in machines to improve efficiency	5	42%	11	37%
	Cost control	4	33%	19	63%
	Recycle waste paper	0	0%	5	17%
	Monitor demand	0	0%	10	33%
	Optimised work (efficient)	0	0%	1	3%
	Minimise waste	0	0%	1	3%
Recruited and trained personnel to meet the production demand	Improve labour performance (training)	0	0%	2	7%
	Management skills (costing & efficiency)	0	0%	1	3%
	Stringent supervision	0	0%	1	3%
	Increase labours	0	0%	1	3%
Others	Marketing promotion	1	8%	0	0%
	Supply chain management	0	0%	1	3%
	Target lower income group for lower quality papers	0	0%	1	3%

Note : Frequency count reflected a mixture of methods. Solvers may use more than one method from the above mentioned.

It is interesting to note that about 50% (6) of the SS considered solving the problem using the method of 'Planning for production plan' while 63% (19) and 57% (17) unsuccessful solvers considered the methods of 'Monitoring costing and efficiency' and 'Monitoring production process / reduce changeover time' respectively.

The details of the cognitive processes of the SS and US were further explored through three perspectives: (a) to identify the solution path based on participants' written work; (b) to describe the solution path based on the triangulated information from participants' 'think-aloud' verbatim, retrospection from the interview and the researcher's field notes; additionally, the solution path was also presented in a flow chart to picture the flow of thought of the solver; and (c) to summarise the solution path into a problem. Attention is also directed to step(s) which reveals behaviour of retrospection in the process of problem solving. Anderson et al's OR model and 7-step decision making/ problem solving model are coded to examine the concept and strategies adopted by the participants in solving the IS-MS problem.

4.1 The cognitive processes of successful solvers

There were 12 successful solvers, 50% of them (6 participants) solved the problem by suggesting a review of the master production plan/monitor the production plan. The second popular suggestion was to monitor production process and monitor quality of inputs and outputs issue which contributed to the current problem by the way machines operated. And the third one was to monitor the cost and efficiency. In short, the above mentioned three methods were among the popular choices targeted by successful solvers to solve the IS-MS problem in order to improve the production performance. Example of the cognitive processes demonstrated by the selected successful solver (SS) HTR015 is shown in Exhibit 1, 1a and 1b.

Exhibit 1: The Solution Path of Participant HTR015 (SS) in Solving the IS-MS Problem

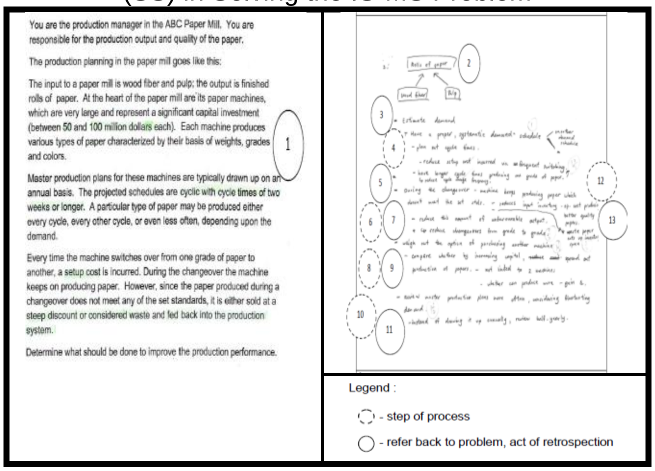
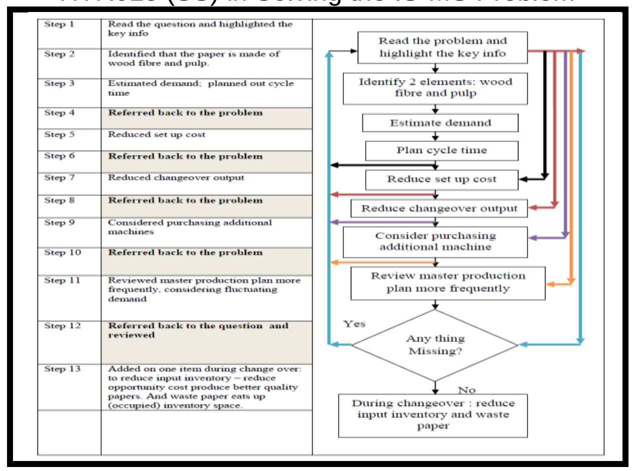


Exhibit 1a: Description of the Solution Path of HTR015 (SS) in Solving the IS-MS Problem



In the case of SS HTR015, the participant focused on the demand schedule to plan out the cycle times properly which helped to reduce the setup cost incurred due to frequent switching. He suggested reducing input inventory and changeovers, considering to invest in more machines and reviewing master production plans more frequently due to fluctuation of demand. By doing so, the production performance could be improved.

The problem solving processes from SS HTR015 which resembled the Anderson et al's 7-step problem solving process in solving the IS-MS problem can be summarised and shown in Exhibit 1b.

Exhibit 1b : The problem solving processes of participant HTR015 (SS) for IS-MS problem

Identify the problem → Determine the set of alternatives →Evaluate the alternatives →Implement the selected alternative→***Refer back to the problem*** →Evaluate the alternatives →Implement the selected alternative→ *Evaluate the results* → ***RE-view the selected alternative***→ *Implement the selected alternative*

It was noted that the processes adopted by the SS HTR015 resembled closely to Anderson et al's 7-step problem solving processes, except the processes of '*Refer back to the problem" and "RE-view the selected alternative".* They indicated the steps of retrospection between each alternative determined and its implementation as well as at the last step "to review and evaluate the selected alternatives".

In view of all the SS, the problem solving processes followed a non-linear solution path. They revealed steps of retrospection for each solution suggested. This reflected that they constantly monitored their cognitive processes during the problem solving processes, retrieved their prior knowledge and tried to make inferences to the problem.

4.2 The cognitive processes of unsuccessful solvers

There were 30 participants categorised as unsuccessful solvers (US). As many as 63% (or 19) of participants approached the IS-MS problem by focusing on the cost control, 57% (or 17) participants considered that monitor production process or reduce changeover time would result in improving production performance. Other concerns were about the machinery (37%) and monitoring demand (33%). Improving the machinery or upgrading the machines and managing production demand properly would help to improve production efficiency. Most US did not critically analyze the problem and their answers were quite brief. A selected example of US HCG013 is shown in Exhibit 2, 2a and 2b for further illustration.

Exhibit 2: The Solution Path demonstrated by HCG013 (US) for the IS-MS problem

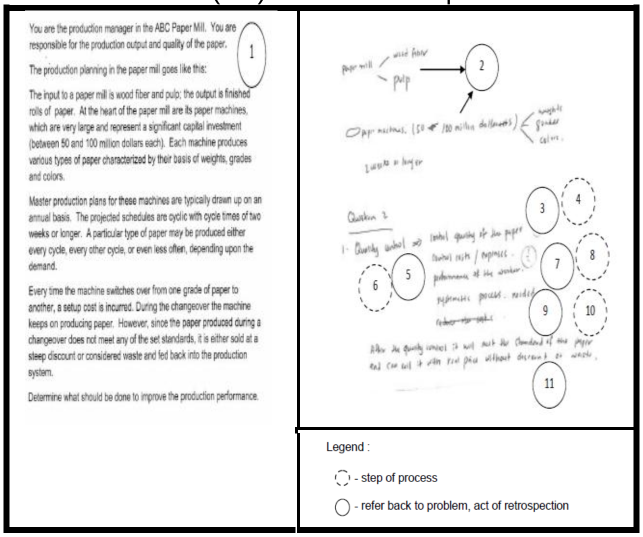
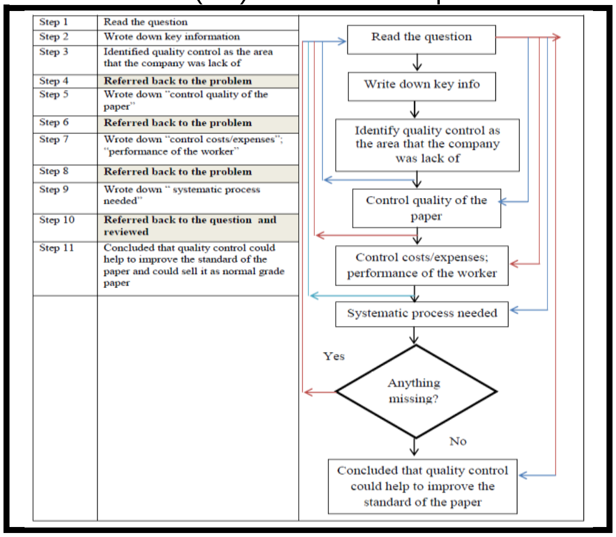


Exhibit 2a: Description of Solution Path of HCG013 (US) for the IS-MS problem



US HCG013 attempted the problem by focusing on quality control. She believed that good quality of raw materials as inputs would produce good quality of outputs. Thus, by controlling on the quality of inputs such as costs, processes and performance of the workers, the output of the papers would meet the standard and there was no need to sell the papers at a discount or treated it as waste.

The problem solving processes of US HCG013 by resembling to Anderson et al's 7-step problem solving process in solving the IS-MS problem is summarised and presented in Exhibit 2b

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Exhibit 2b : The Problem Solving Processes of HCG013 (US) Solving the IS-MS Problem

Identify the problem → Determine the set of alternatives →Evaluate the alternatives →Implement the selected alternative→***Refer back to the problem*** →Evaluate the alternatives →Implement the selected alternative→ *Evaluate the results* → ***RE-view the selected alternative***→ *Implement the selected alternative*

It was noted that the processes adopted by HCG013 (US) resembled Anderson et al's 7-step problem solving process closely except "*Refer to the problem" and "RE-view the selected alternative'.* She indicated the steps of retrospection between "evaluate the alternatives" and "implement the selected alternative". In addition, she indicated a final retrospection at the last step to review and evaluate the selected alternatives.

In view of the cognitive processes of all US, regardless of what approaches they adopted to solve the problem, all of them did not fully resemble to Anderson et al's 7-step problem solving process. Depending on the individual's problem solving competency, they normally managed up to the first five steps. However, their solution paths were not in a sequential process or linearization. Retrospection was revealed between the process of "evaluate the alternatives" and "implement the selected alternative". This is one of the author's contribution to the new knowledge.

4.3 Strategies of successful and unsuccessful problem solvers

Strategies employed by SS and US to solve the problem were also examined through the models developed by Anderson et al (2013). It was noted that SS resembled closely to the Anderson et al's 7-step problem solving models, they seemed to stop at the point where implementation of decision was carried out. For the US, they generally resembled to strategies developed by Anderson et al, but not to the extent of every strategy. It was not easy to identify a clear-cut strategy for every strategy used, at times, it reflected a combination of two strategies. However, one common phenomenon noted was that both SS & US did not employ the "evaluate the results" (Anderson et al's) strategy. They did not review their solutions when they "finished" solving the problem. This might be due to the fact that they knew that their solutions were not bounded to any fixed solution, as long as their solutions/suggestions were justified. Tables 3 and 4 respectively show a summary of the cognitive processes and strategies of successful and unsuccessful solvers in solving the IS-OR problem.

Table 3: Summary of the Cognitive Processes and Strategies of SS in Solving the IS-MS Problem

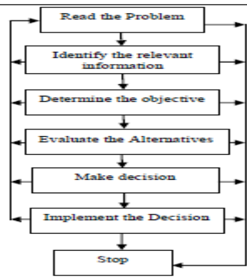
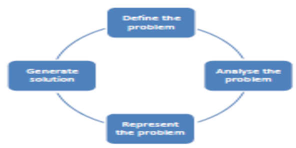
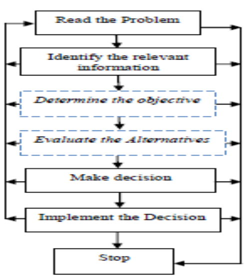
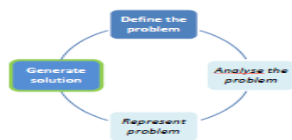
Cognitive processes	Processes in Flow Chart	Strategies	phenomena:
Steps: 1) Read the problem 2) Identify the relevant and concerns 3) Determine the objective(s) 4) Evaluate the alternatives 5) Make decision 6) Implement the decision		• Define the problem • Analyse the problem • Represent problem • Generate solution 	• Have clear understanding of the problem and concept of the subject, able to present the problem according to their own thinking. • Relevant knowledge (prior knowledge) acted as a rich resources to determine the success of decision making and problem solving. • Relevant knowledge helps develop creativity in solving similar problems • Retrospection was demonstrated at solution point, but not at the final stage.

Table 4 : Summary of the Cognitive Processes and Strategies of US in Solving the IS-MS Problem

Cognitive processes	Processes in Flow Chart	Strategies	Phenomena:
Steps: 1) Read the problem 2) Identify the relevant information *3) Determine the objective* *4) Evaluate the alternatives* 5) Make decision 6) Implement the decision Note : Steps 3 and 4 appeared to be case by case		• Define the problem • *Analyse the problem* • *Represent problem* • Generate solution  • Note : Application of strategies of *"Analyse the problem" and /or " Represent problem" is case by case*	• Understand the problem superficially • Lack of in-depth analysis on the problems/issues • Suggested solution implied lacking of MS knowledge and exposure. • Retrospection was demonstrated at solution point, but not at the final stage.

5. Summary and Conclusions

To sum up the cognitive processes of participants in solving the IS-MS problem, no matter what solution paths both SS and US participants have adopted, it was noted that the solution paths were not in a straight and sequential manner, participants would constantly retrospect to the problem when a possible solution was recommended. They tried to search for clues from the question to identify every possible solution to improve the production performance as required by the question. It was also noted that the main difference between SS and US was very much dependent on the individual's prior OR knowledge, understanding of the problem and his/her problem solving skills. This was reflected by the individual solver's various degrees of exposure to the MS environment and its related issues. In addition, the study indicates that the SS tended to explore more alternatives to solve an MS problem by looking into the various possible perspectives when compared to US. US were limited by the constraints of their MS knowledge and sometimes, problem understanding and problem solving skills.

One interesting point to note was that when solving the IS-MS problem, participants seemed to know that there was no one convergent answer, they felt free to make any assumptions they thought was logical and reasonable. Then, they just worked on their assumptions and implemented them according to their thought (Cheng, 2014). They seemed to think that it was not necessary to verify the solutions given. These findings reflect that prior knowledge and personal exposure could probably be the influential factors. These observations could be seen from the many different methods adopted in solving the IS-MS problem. In addition, their personal preference would also be one of the determining factors. In short, participants generally preferred to use their own way to solve the problem and they felt that it was the right strategy to do it, they also felt that verification at the final stage would not be necessary.

In conclusion, problem solving is a complex mental process, regardless of the different types of problems. Solver needs to understand the different functions of the memory system such as the working memory (WM) or short term memory (STM) and long term memory (LTM). By understanding the cognitive processes in problem solving, the solver can self-regulate and motivate his/her learning ability. In order to acquire a competency level in problem solving, a solver has to possess the domain-specific knowledge and problem solving experiences. The heuristic steps can act as guidelines to facilitate the efficiency in problem solving by reducing the irrelevances. The choice of strategy depends on experience and can be improved through learning and practising various types of problems.

In view of the findings of this study, it is suggested that educators and instructional designers should expose learners to various types of problems across multiple domains; provide them opportunities to find or identify problems. The solvers should be taught how to explore the experience on defining problems and make individual meanings by themselves, conceptualize problems and problem states, consider methods or procedures to visualize and construct goal states. In addition, learners should be provided with opportunities to consciously reflect about their own thinking (Bransford & Stein, 1984; Bransford et al., 1986; Mayer, 2008). In a nutshell, educators and instructional designers should make learners "think" and get used to messy problem situations (Cheng, 2014). We must recognize and understand that "individuals use complex mental processes to survive and adapt in a problematic world" (Sinnott, 1989, p.1). "Problem solving is a key competency in a world full of uncertainty (Osman, 2010) and full of potential obstacles on our way to society goal states of peace, food, and justice." (Funke, 2013, p.3)

Furthermore, OR is a subject particularly dealt with problem solving, with the increase popularity of OR practices in Malaysia, education administrators may consider to offer OR as a subject, be it a core or elective subject, in the undergraduate degree programme. It is believed that undergraduates could improve their problem solving skills if they learn the OR subject effectively.

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