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Performance of Undergraduate Students in Mathematical Problem Posing Tasks

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Abstract

The mathematical problem posing tasks are relevant issues in the development of higher education curriculum and improving it for developing nations require its inclusion in the curriculum as a complement to problem solving tasks. We investigate the types of problem posing abilities, related difficulties and levels of performances in “calculus-1” among first year undergraduates in Iran. The research instrument consists of text book "integral" problems reconstructed through "add or remove condition" with structured situation and "change the problem context" with semi-structured situation. Twenty-six first year undergraduates among moderate and high achievers are participated in answering the test. Furthermore, five of them are enrolled in semi-structured interview after the test. The preliminary results reveal that the percentage of "expert" students (69%) in generating problem through "add or remove condition" strategies are higher than those (18%) implementing "change the context" which is connected to high-order-thinking skills. However, the majority of participants are greatly able to perform two-third of questions correctly. The significant weakness related to the conceptual and procedural understandings in terms of the high-order-thinking skills are observed among them. We assert that the students’ problem posing performances can be fostered by incorporating problem posing activities in teaching-learning materials.

Keywords: Problem posing abilites; problem posing difficulties; high-order-thinking; undergraduate students' performance

Abstrak:

Tugasan berbentuk pengutaraan masalah adalah merupakan satu isu yg relevan dan juga komponen penting dalam pembangunan kurikulum matematik di peringkat pengajian tinggi khasnya di negara sedang membangun. Pengkaji telah menyelidiki beberapa jenis kebolehan, tahap pencapaian dan jenis kesukaran pengutaraan masalah dalam kalangan pelajar tahun 1 peringkat sarjana muda di negara Iran. Instrumen kajian mengandungi soalan soalan dalam tajuk pengamiran yang dibina melalui penambahan dan penyingkiran syarat dalam situasi berstuktur dan perubahan konteks soalan dalam situasi separa berstruktur. Dua puluh enam pelajar daripada kalangan pelajar berpencapaian sederhana dan tinggi telah dipilih untuk menjawab soalan ujian berkenaan. Selepas ujian, lima daripada mereka, dilibatkan dalam sesi temu bual separa berstruktur. Keputusan kajian menunjukkan bahawa peratusan pelajar yang mahir (69%) dalam aktiviti menjana soalan melalui strategi penambahan dan penyingkiran syarat adalah lebih tinggi daripada mereka yang melaksanakan starategi perubahan konteks soalan (18%). Majoriti pelajar telah menunjukkan kebolehan cemerlang dengan dapat memberikan jawapan yang betul kepada soalan soalan yang dikemukakan. Kelemahan ketara pelajar adalah yang berkaitan dengan masalah pemahaman konseptual dan juga penguasan kemahiran aras tinggi. Akhirnya pengkaji menyarankan supaya guru menyediakan bahan pengajaran dan pembelajaran yang melibatkan aktiviti berbentuk pengutaraan masalah untuk meningkatkan kemahiran pelajar dalam aspek tersebut.

Kata kunci: Kebolehan pengutaraan masalah; kesukaran pengutaraan masalah; pemikiran aras tinggi; pencapaian pelajar sarjana muda

■1.0 INTRODUCTION

There are high expectations in terms of analytic and creative knowledge-based power on higher education graduates as a work force with accurate decision-making ability or scientist who want to combine mathematics with other areas. To achieve these goals, one of the major concerns in Iranian mathematics undergraduate curriculum (2004) is engaging students in mathematical problem solving situations for promoting high-order-thinking among them particularly in "real life" situations. Furthermore, due to problem solving approach that leads learners to convergent thinking, teaching and learning materials in higher education must be equipped to valid activities such as problem posing as complement problem solving process by developing divergent thinking among undergraduates. Over the decades, the educational experts (e.g. Kilpatrick, 1987; NCTM, 2000) have reached to the consensus that problem posing could help students in improving their problem solving abilities as well as skills including planning, monitoring progress, making effort calculations, decision making, checking work, choosing strategies, and so on. Despite such enormous achievement, problem posing approaches remained less-known in pedagogy of major developing nations. Particularly, in Iran, adequate studies are not been made related to the performance in mathematics problem solving among undergraduates as a result the problem posing approach is generally unknown in this pedagogy (Ghasempour, 2011).

The importance of problem posing is discussed by Stephen Toulmin in 1997 (Brown & Walter, 2005). Later on, researchers have gradually begun to realize that developing the ability to pose problem as highly significant issue in education. The Professional Teaching standards pointed out that "students should be given opportunity to formulate problems from given situations and create new problems by modifying the conditions of a given problem" (NCTM, 1991). Various definitions of problem posing have been presented by researcher, such as problem posing is as a part of problem solving (Polya, 1954). This creative activity can described as a way for developing problems, exercise of real life situations, a mean of instruction, a communicate mathematically and a tool diagnostic (e.g. Kilpatrick, 1987; Abu-Elwan, 1999; NCTM, 2000). Totally, problem posing skills contains mental skills, where students may use the given condition in the problem to reformulate the given problem (Abu-Elwan, 1999). This skill can lead mathematics teachers to measure students' understanding of mathematical concepts. Therefore, mathematics teachers should emphasize on problem posing tasks, instead of problem solving tasks alone for challenging learners to the quality problems whose solution strategies are not immediately known to each student. According to these views, there exist various strategies that learners could apply one or more them to formulate new appropriate problems in a flexibility method, such as "What if" or "What if-not?" strategy that Brown and Walter (2005) designed it based on the posing of new problems from already solved problems with varying the conditions or goals of given problems. This method, through the process of asking "What if" or "What if not?" can change each component of the problem, such as the numbers, the geometry, the operation and the context. Another strategy is called "Modifying givens" strategy (Bairac, 2005) consist of paraphrasing, changing of statement's data, analogy and generalization. In analogy and generalization are emphasized on replacement a condition or add new conditions, remove or add context and repeat a process. In this regard, strategies can be used depending on the most suitable conditions, such as mathematics contents, students' levels, learning outcomes and mathematical thinking types (Abu-Elwan, 1999; Stoyanova, 2003). Meanwhile, each of strategies could be performed through particular situations, namely free, semi-structured and structured situations. Free situations are when students posed problems without any restriction, such as everyday life problems. Semi-structured situations occur when students are asked to construct problem similar to given problems, problems with similar situations, problems related to specific theorems, problems derived from given pictures and word problems by using knowledge, skills, concepts and relationships from their previous mathematical experiences. Besides, structured situations arise a appropriate environment for generating problems by reformulating already solved problems or by varying the conditions or questions of given problems (Abu-Elwan, 1999; Stoyanova, 2003).Therefore, problem posing situations emphasise to thinking about the relationship between mathematical ideas more than doing a mathematical activity, as a result can stimulate high-order-thinking and divergent thinking in learners which are aimed in higher education as the mathematics' learning outcome. Hence, a comprehensive study is required for establishing patterns of mathematical problem posing among undergraduates and investigating their strengths and weaknesses in these takes.

This study uses two materials as the problem posing activities such as "posing mathematical problems from given textbook problems" (Abu-Elwan, 1999; Ilfi & Md. Nor, 2010) and "Everyday life" (Akay & Boz, 2010). According to this view, there are two phases in the solution process during which new problems can be created, the solver can intentionally change some or all of the problem conditions in two different ways using problem posing strategies "Change the problem context" and "Remove a condition or add new conditions" to see what new problem might result that this step is called to "phase 1". In "phase 2" this new posed problem has been solved, then the solver can look back to see how the solution might be affected by various modifications in the problem. Figure 1 illustrates this approach through a conceptual framework that is a modification of Abu-Elwan's (2002) framework in cyclic of activity problem (solving-posing). Consequently, this framework is proposed for evaluating the types of problem posing abilities, related difficulties and levels of performances through "calculus-1" among Iranian first year undergraduates. It is expected that this research can especially encourage teachers of developing nations for designing required materials encountering mathematics classroom with problem posing situations which can be implemented in a social constructivism environment.

2.0 MATERIALS AND METHOD

2.1 Tasks and Administration

The study involved the use of exploratory method. It consisted of the integration of quantitative and qualitative approaches. Quantitative approaches were used to investigate the undergraduates' abilities, related difficulties and levels of performances in problem posing activities through their written work of test interventions. On the other hand, qualitative approaches were used to identify more justifications about test's outcomes through semi-structured interview interventions. In "phase 1" test session, undergraduates were asked to generate new themselves problems individually for using inductive analysis. Continually, during the "phase 2" participants were requested for solving new posed problem, then teacher-researcher asked the two following questions:

(a) Does the problem posing strategies leads to a solvable and unsolvable problem?
(b) Is the solution of the created problem totally different from the solution of the initial problem or are there only cosmetic changes in the solution?

Discussing the above issues while engaging in problem posing activity using the "What if not?" strategy (Brown & Walter, 2005) might be regarded as educational benefits of the activity in a conxtroctivist environment. In addition, field notes of classroom observations were conducted in "phase 2" for more evidence.

Eventually, participants were asked what their difficulties were during problem posing activities. The role of the research-teacher for the study was as a "complete participant" because she was the primary instrument of data collection and analysis (Ilfi & Md. Nor, 2010).

The respondents were twenty six first year undergraduates from various faculties at Islamic Azad University (Birjand Branch) that were involved in answering the test. Participants were selected purposefully among moderate and high achievers who could be expected to have literacy levels sufficient to understand questions and articulate in their posed question processes by researcher regard to their mark in final exam of "caculus 1" course. Most importantly, they were first encountered in problem posing tasks. After test session, five of them were selected for the semi-structured, task-based interview that was performed as one-by-one.

The individual interview was utilized for two goals. Firstly, researcher can gather more in-depth responses by expressing participants' thoughts as problem solvers. Secondly, it could clarify responders 'strategies used. A copy of each problem is presented to the participants by the research-teacher and each participant is then asked to respond to the question and make a written recording of any working out used in the process. During the interview, research-teacher inquired a purposeful questions regard to revised Bloom's taxonomy (see Appendix 1) as a way to ensure that respondents got beyond the simple answers and were thinking more deeper, additionally questions were prompted when clarification was requested. Following the completion of each problem, individual participant is asked to verbally explain their difficulties related to problem posing tasks. The interview is then audio-taped.

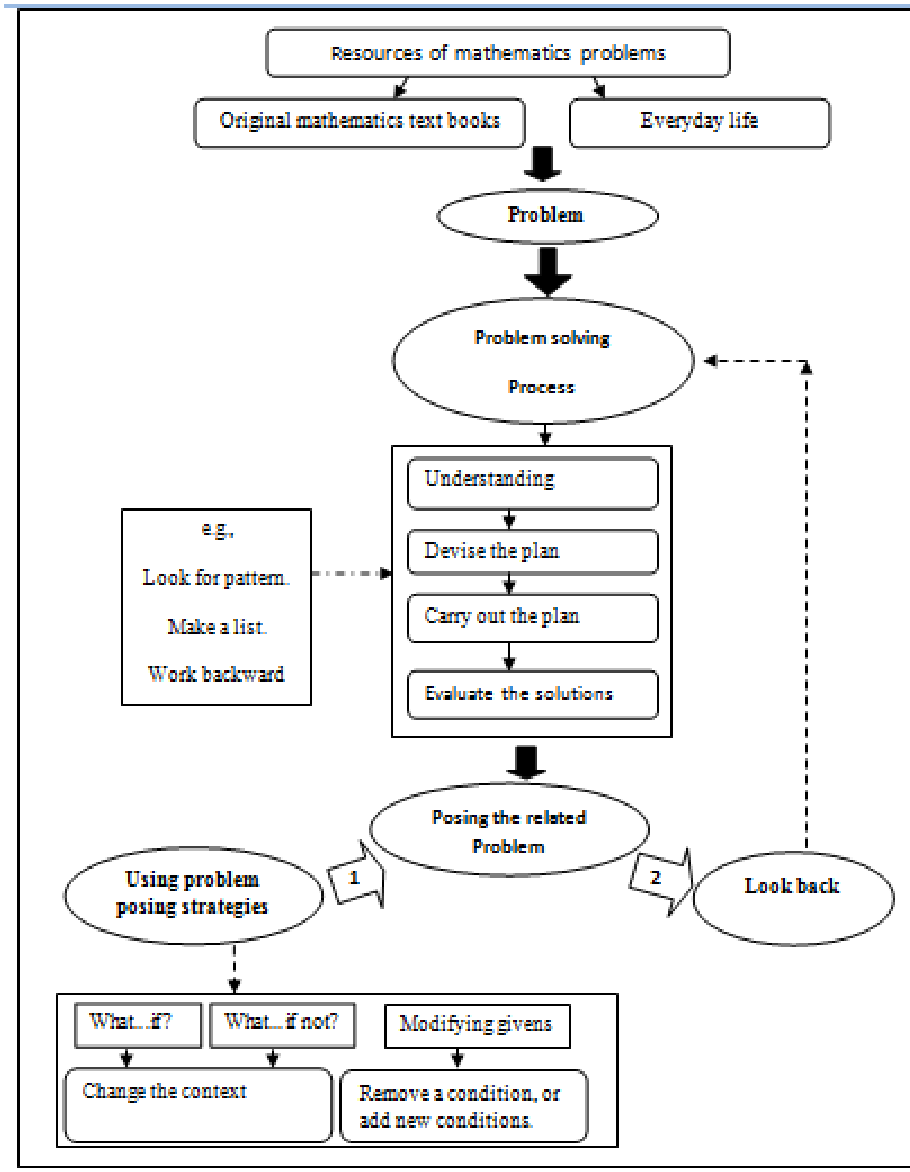

Figure 1 Proposed conceptual framework of this study

2.2 Problem Posing Tasks

Tasks were designed based on "integral" section that is one of fundamental concepts in "calculus 1" and build a basis for more advanced mathematical subjects. According to research conceptual framework, each of tasks was consisted two parts. Part (a) involved students in problem solving strategies and Part (b) as problem posing. Besides, "add or remove" and "change the context" strategies were considered as problem posing strategies that were performed through structured and semi-structured problem posing situations respectively. Structured problem posing situation is chosen in order to reveal the structure of students' mathematical abilities, such as ability to understand of the techniques used to solve a problem, or analysis of the underlying mathematical structure of given models. Furthermore, semi-structured situation is purposed as a method that could be described a concrete situation to a mathematical abstraction by symbolic expressions, enhance creative writing skills, clarify some student's difficulties in mathematics' concept understanding as well as problem solving, and conclusively construct mathematics more meaningful for learners. Meanwhile, the researcher selected and modified 20 problems related to "definite integral definition", "techniques of integration", "fundamental theorem of calculus and their results", "application of integration in finding area, volume". These problems were chosen from textbooks Thomas 'calculus (2005). After reconstructing problems according to the experts' suggestions, 5 questions for section B of test and 3 questions for each of sections C, D interview session were selected. Two examples of problem posing tasks through the study are presented in Table 1.

Table 1 Two problem posing tasks involved in this study

(a) Calculate $\int_{-1}^{4} |x-3|dx$ by drawing the graph.

i. Determine problem's Condittions exactly,then solve it.

ii. $|X-3|$ is differentiable everywhere except for $x = 3$,therefore how do you justify its integrability in $[-1,4]$.

(b) Construct a definite integral problem for " piecewise continuous function".

i. Determine problem's Condittions exactly.

ii. Solve the new problem .

iii. How do you justify integrability of posed problem by connention to theory " characterizations of integrability concerned to continuity".

Find the volume of the solid generated by revolving about x-axis the region bounded by curve y= e^{-x} ,y=0,y=1

i. Determine problem's Condittions exactly, then solve it.

Generate a problem involving definite integral that compute the volume of a solid item that you use in daily life.(Note: items same Birthday hat,a vase, a ring,a ball,,,,)

i. Determine problem's Condittions exactly. and explain how evaluate new conditions.

ii. Solve the new problem .

■3.0 RESULT AND DISCUSSION

3.1 Level of Undergraduates' Performance

A rubric was designed for assessing students' attempts in mathematical problem solving- posing (see Appendix 2). This rubric is a rearrange of rating scales that were used by Abu-Elwan (2002) in their studies with regard to problem posing tasks.

The preliminary results stress that the majority of participants were "Expert" or "Practitioner" in solving "original textbook problems" (89.23%). In other words, these participants' responds scored ratings of "6" or "5" in solving "Original textbook problems", then they completely understood the conditions and demands of the "original textbook problems" as well as were able to solve problems correctly or with minor erroneous. Only less than twelve percentages of students' responses received a rating of "0" to "4" indicating a sound misunderstanding of what the problem required them to do, especially in real life problems and tasks were derived from the mathematics theorem. Therefore, data analysis identify that this participants were moderate or high-achiever in solving "original textbook problems."

According to findings, more than three quarters of participants (80.77%) were "Expert" or " Practitioner" in posing problems with "add or remove condition" strategies that were performed in structured situation. These levels of performances indicate participants completely understood of these strategies and were able to generate new problem via them. Only 19.12% of students' responses received a rating of '0' to '6', indicating a sound misunderstanding of what the problem required them to do. Furthermore, it was found that the number of undergraduates' responses received a rating of '9' for "add a new condition" and "remove a condition" stages were 19 and 17 respectively. Hence, this means that students were "more able" in generating "add a new condition" if compared to "remove the condition". The findings are comparable to the findings which obtained by Ilfi & Md. Nor (2010). In contrast, the level of performance participants sharply declined in "change the context" strategies that were implemented in semi-structured situation. More than half of participants (68.31%) were "Novice" or "Apprentice" meaning that they had basic difficulties in problem posing process. Only 17.30% of undergraduates' responses received a rating '9', namely were able to determine the data and the information need to be found, constructed correctly a new problem and interpreted completely new posed problem's condition and demand. This result can be supported by results that Lavy and Bershadsky (2003) reported about less tendency students in generating problem including a change of problem's context, if compared to posing problem including a change of problem's data.

3.2 Problem Posing Abilities

The results asserted that participants indicated ability in understanding and implementation "add or remove condition" strategies, so that, according to hierarchy of the offered by Leung and Silver (1997), 24 of participants constructed solvable problem in both strategies "Add and Remove condition". However, 73% of new conditions and demands were cosmetic and only 15% of new conditions and demands were completely correct and different with initail problem. Meanwhile, 2 of participants constructed unsolvable problem that were able to present reasons for unsolvably new posed problem and correct themselves after teacher-researcher'sguaidance. Furthermore, a ability in procedural mathematics understanding was indicated through this structured situation related to "techniques of integration". Similarity, in "change problem context" strategy that was proposed in constructing another problem related to "techniques of integration", more than half of participants (18) constructed one solvable problem or more than one, however the majority of these new problems had a cosmetic changing. In these tasks, undergraduates presented a range of procedural understandings such as representing mathematical patterns, structures and regularities, using deductive arguments to justify decisions for new posed problem based on given data, and generating new problem via mathematical connections. Another, undergraduates indicated mastery in generating problem derived from a given graph involved in "application of integration in finding area" by "change problem context" strategy. All of participants constructed solvable problem with in-depth changing. In this situation, paticipants were able to justify and support decisions made and conclusions reached by given graph and mathematical connections in term of procedual understanding. The validity of findings can be verified by Lavy and Bershadsky (2003), and Abu-Elwan (2002). In a similarity way, they found out that almost half of the posed problems consists of a specific change (numerical value, data kind), or good problems which consisting of new ideas in their conditions or in demands. On the other hand, there are only a small number of posed problems as usual problems including implicit or formal generalization versus problems with another specific or a range of values. Most importantly, the majority of participants were able to perform routine procedures and basic techniques of integration as Mahir (2009) discussed in her study. Whilst, during the test session observed when students was asked that argued with peers about solvable or unsolvable their posed problem, they rarely could explain their procedures due to limitation understanding of the underlying concepts. After discussion, they admitted that they now really know why they were doing it, and then it can be considered as results of implementing valid tasks such as problem posing that can enhance conceptual understanding among undergraduates.

3.3 Problem Posing Difficulties

This study founded that undergraduates had the most difficulties in using "change the context" strategies for generating problems related to "characterizations of integrability concerned to continuity" and "application of integration in finding volume a real object" (See Table 1). In this study, specific theorem "characterizations of integrability concerned to continuity" was proposed to investigate undergraduates' ability in evaluation underlying concepts that can be connect to "definite integral definition" via a problem posing task. Eleven of participants misunderstand problem, as a result constructed incorrectly a new problem or no attempt for it. Nonetheless, resultes asserted that the majority of students were able to make a solvable problem, due to conceptual understanding difficulties, all of them were unable to interpret correctly their answers or even generalize the agreed situation part (a) via the mathematical term. In addtion, class observation revealed that they were less familliar with some theories and definition such as the "piecewise continuous function" characters, "Floor and Ceiling functions" and "characterizations of integrability concerned to continuity" theorem. This findings can be justified by results' Mahir (2009) that investigated how conceptual and procedural can involved in variety subjects of calculus as well as found that participants' conceptual understanding is lower than their procedural understanding , namely they have been unbalanced by trainings technique-centered. On the other hand, according to a revised measure/process descriptors adapted from Bloom *et al.* (1956), this situation alerted a difficulty in representation and connection steps, namely participants' responds indicated weakness them in representation basic theorems as a cognitive aid and constructing a novel link between two existing mathematics concepts. Most significant, undergraduates indicated some difficulties during the "Everyday life" tasks. So that, half of them them were unable in constructing new problem in real life situation. With regard to interview results, the researchers found that several factors contributed in students' difficulties through these problem posing activities. Unfamiliar with the topic, lack of skill for drawing a simplified graph based on a real object to relate the topics with real life situations (simulating) and disability to use precise math language and symbolic notation to consolidate math thinking were some of the major difficulties. Furthermore, 65% of them stated that had generally difficulty in solving questions related to volume. Besides , they had mistake in algabric caculations, and bounds of integral that indirectly pointed out not used simply lookback again for checking solution.Consequently, these conditions can report a weakness in high-order-thinking skills among undergraduates, such as analysing, evaluating and creating regard to Bloom's taxonomy.

The examples of their responses are as follows:

Interviewer: Why can't you construct a problem for evaluating volume a real object such as ball, hat...?

Subject 1: "*I haven't learned it yet, namely in all of prier problems functions were recognized*"... (Unfamiliar with the topics.)

Subject 4: *"I don't really know how draw a graph of real object that can create a formula for evaluating volume it"*... (Lack of skill for drawing a simplified graph based on a real object.)

Subject 2: *"I know that a simple graph for a ball can be a circle, therefore I must find a suit function that can evaluate volume ball based on integral this function. But I don't know what define this function"*... (Inability to use precise math language and symbolic notation.)

subject 5:" *I forgot to check my solution regard to algabric caculations*"... (Not used simply lookback.)

■4.0 CONCLUSION

The results indicate that the variety of mathematics skills, such as representing, reasoning, problem solving, formulization, communication, justification, simulation and abilities related to each of them are involved in problem posing tasks through structure and semi-structured situations. In addition, it is observed that the significant difficulties through problem posing tasks could be followed as misunderstanding the problem context, difficulties in cognitive knowledge, low level of conceptual understanding and weakness to justify the validity of new condition for everyday life problem. Despite such difficulties, due to more than half of the students are greatly able to perform two-third of questions correctly, students' problem posing performances can be fostered. On the other hand, during the interview session was observed in contrast with Polya's linear model that meta-cognitive awareness appears only at the looking back stage, undergraduates meta-cognitively monitored the problem solving-posing process and their transition from one stage to next stage occurred as nonlinear. As a result, we suggest directions for further research that may be undertaken in order to improve proposed problem posing framework regard to meta-cognitive knowledge. In addition, we assert that the teaching-learning material consisting of problem posing activities that enhances teaching and learning mathematics must be incorporated in higher education curriculum.

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Appendix 1

Categories of semi-structured interview questions based on cognitive process dimension.

Cognitive Process Dimension	Questions/Directives
Remember	Can you recall "definite integral definition" ,"techniques of integration"," fundamental theorem of calculus and their results"," application of integration in finding volume and area" ....? Which types of problem posing strategies do you prefer? What are your difficulties during the problem posing tasks? What are your difficulties when posing problems related to the real life situations?
Understand	What are the conditions of this section of problem? What are the demands of this section of problem? Can you determine the data and the information need to be found? Compare given data part (a) and (b).
Apply	Know exactly what to do next. If you are unsurely, do whatever that seems logical through reasoning. Improve the plan (another way). Need to arrange the information Can you carry out the problem posing strategy? How would you construct a new condition by "changing the context" strategies for posing a new problem? How would you construct a new demand by "changing the context" strategies for posing a new problem? What is new condition that you would add or remove to previous condition? What is new condition that you would add or remove to previous condition? How would you evaluate your question / Can solve new problem?
Analyze	How would you analyze the situation in mathematical terms, and extend prior knowledge presented in part (a)? Can you identify that new problem is solvable or unsolvable? What is the meaning of the answer? How do you justify the logic of the answer? Conclude a significant pattern or structure.
Evaluate	How would you justify and support decisions made and conclusions reached by drawing a graph related to a mathematical theory? Simply look back again (recap). Checking the logic of the equation arrangement. Checking the answer by interpreting. Reading to see if the goal is achieved as required by the question.
Create	Can you design a math graph related to a real subject? Can you generate the problems in yours words regard to formal math language? What changes would you make to solvable new posed problem? Can you construct more than 1 new problem?

Appendix 2

Rubric for assessing students' attempts in mathematical problem solving –posingStudents would be classified as:

Rating scale for Problem solving- posing	*Rating scale for Problem solving- posing*	*Rating scale for Problem solving- posing*	*Rating scale for Problem solving- posing*
Complete interprets the problem's condition , demand in part (a) and solve it correctly. (2,2,2). Complete interprets problem's given condition and demand in part (b)/ (c) (1,1). pose new condition and demand correctly (1,1). complete interpret posed problem's new condition and demand (1,1). & Complete posed problem (write problem exactly& solve)correctly (3) .	Complete interprets the problem's condition , demand in part (a), and solve it with minor incorrectly (2,2,1) . Complete interprets problem's given condition and demand in part (b) /(c) (1,1) pose new condition and demand correctly (1,1) complete interpret posed problem's new condition and demand (1,1). & Complete posed problem with minor incorrectly (2).	A partially correct interprets the problem's condition , demand part (a) and solve it with incorrectly (1,1 ,0) . A partially correct interprets problem's given condition or demand in part (b) / (c) (0,1) A partially correct pose new condition or demand correctly (0,1). A partially correct interpret posed problem's new condition or demand (0,1). & Complete posed major problem incorrectly (1).	No attempt or completely misinterprets the problem's condition , demand part (a) and solve it incorrectly (0,0 ,0) . No attempt or completely misinterprets problem's given condition and demand in part (b) /(c) (0,0) No attempt or pose new condition and demand incorrectly (0,0) No attempt or completely misinterprets posed problem's new condition and demand (0,0). & No attempt or complete posed problem incorrectly (0).

- The **Expert** performer if he/she is able to receive a total rating of "6" of problem solving & "9" of problem posing for the given questions.
- The **Practitioner** performer if he/she is able to receive a total rating of "5" of problem solving & "7, 8" of problem posing for the given questions.
- The **Apprentice** performer if he/she is able to receive a total rating of "3, 4," of problem solving & "4, 5, 6" of problem posing for the given questions.
- The **Novice** performer if he/she is able to receive a total rating of "0, 1, 2" of problem solving & "0, 1, 2, 3" of problem posing for the given questions.