An Investigation into the Creative Problem Solving Skills of Gifted Students[1]

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Abstract
In the Turkish education system, it is aimed to educate gifted students in particular, as investigative and inquisitive individuals who have the ability to think critically and creatively. In this respect, the creative problem solving abilities of 21 students, studying at Balıkesir Sciences and Arts Center in the second semester of the academic year 2013/14, identified as gifted by the Counseling and Research Center (CRC) and who were considered appropriate for taking mathematics courses at the sciences and arts center, were examined. The research was carried out using qualitative research methods, within the framework of a content analysis model.
Key words:
gifted students, creativity, problem solving

1 A portion of this study, IV. Ulusal Üstün Zekâlı ve Yeteneklilerin Eğitimi Kongresi (Üstünler-2014) [IV. The National Gifted and Talented Education Congress (Gifted-2014)] September 22-25, 2014 – İstanbul, reports were presented orally in Turkey.

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Introduction

A widely accepted definition of a problematic concept is that, "When faced with a problem that does not have an immediate solution, the individual's decision is to think about it and reflect upon the issue in order to overcome such a situation" (Akay, Soybaş & Argün, 2006). Problems lead students to investigate/discover patterns and to think critically.

The heuristic thinking approach is a cognitive process used for the solution of specific problems. In the field of education, the term implies the method of guiding the student to discover the subject that is intended to be taught on her/his own, while in the scientific context, it indicates the discipline of exploring events. According to the heuristics approach, there are five steps to problem solving: analysis, planning, research, practicing and testing. The main goal of the problem solving approach is to enhance advanced thinking (Mestre, 1991).

It is suggested that problem solving in mathematics should include complex problems, the solutions of which cannot be seen immediately, and open-ended inquiries, which involve relevant mathematical thinking procedures besides routine problems.

In the literature, mathematical problems have been classified according to various perspectives (Altın, 2005). One of the most important distinctions is to identify problems as routine and non-routine, based on the processes of thought and the effort they require.

With regard to a systematic literature review made by Foong on problem solving and the use of problems, the types of problems promoted in mathematics classes in 21st century classrooms are classified as:

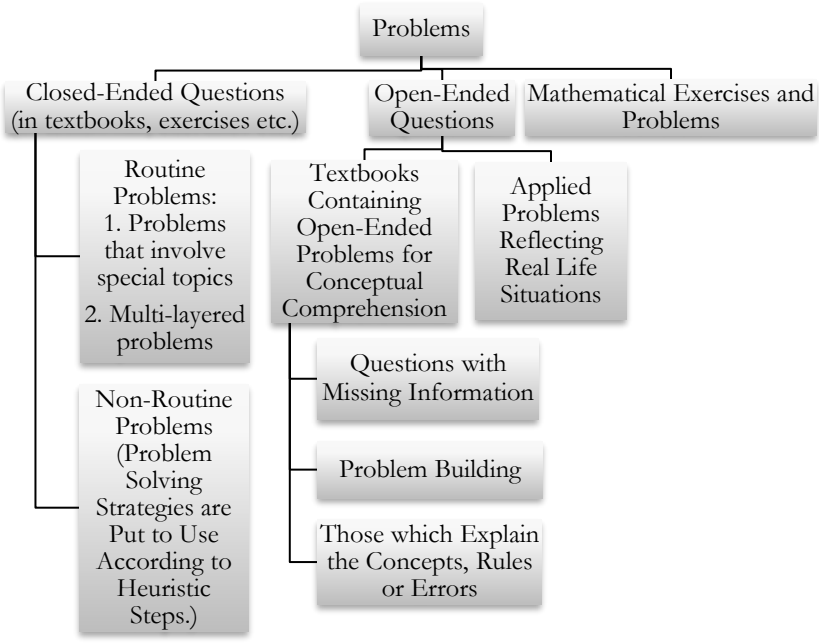

Figure 1.

A Classification of Different Types of Problems (Yenilmez & Yaşa, 2007)

Routine problems are those encountered in everyday life. Simple arithmetic skills are sufficient to solve them, and help the students to improve their computational skills required in daily life and to learn how to express the information given in the problem in mathematical terms.

Non-routine problems, in turn, are those that require more complex thinking compared with routine problems, as the solutions are not obvious.

The importance of problem solving is also mentioned by the constructivist educational approach, which has been frequently deliberated in recent years. This approach prescribes a perspective in which the students shape and construct information on their own. According to the constructivist approach, the purpose of education is to focus on the process of problem solving and one that should be made by considering what natural event lies behind the problem, and knowing and using the methods of thinking that could facilitate a qualitative and quantitative understanding of the event; in other words, teaching how to think like a scientist.

The efforts required to solve the problems are directly related to the cognitive process. 'Thinking' is the basic requirement for solving a problem. Problem solving implies putting thoughts into practice. Being an applied way of thinking, problem solving is in close relation with the other two ways of thinking: these are creative (divergent) thinking and critical (analytical) thinking. If one wishes to develop these ways of thinking in the students, it would be better to use open-ended, non-routine problems rather than close-ended, routine problems. Open-ended problems enhance students' creativity and thinking skills. Diversionary problems support the development of flexibility and different points of view.

Creative problems are commonly used in education, as follows: Students are left alone with an incompletely defined, realistic, complex and meaningful problem. The problem should not have a predictable, or exact, correct answer. In order to provide a solution in the given time, students are left with the problem in small groups, without any constraints, similar to specialists. Thereby, while solving the problem, the student decides on her/his own what to learn and what not learn.

The Importance of the Study

This study should be considered important, as it reveals the problem solving skills of gifted students, hence their ability to assume a positive attitude toward problem solving, and providing them with guidance in the acquisition of creative problem solving skills.

Method

The research was carried out using qualitative research methods, within the framework of a content analysis model. It's purpose was to examine the students' answers to open-ended questions, close-ended questions, questions with missing information, and their approach to questions that require them to pose the problem. Qualitative analysis implies that the researcher has to investigate and examine the facts, which are formed naturally and spontaneously, in all their complexity. The purpose of content analysis, in turn, is to define the data and to

reveal the facts that might be hidden in the data. Basically, the function of content analysis is to bring similar data together around certain concepts and themes, and to organize and interpret them in a way that is comprehensible to the reader.

The Sample of the Study

The proportion of gifted individuals in a society is around 2.5-3%. There were 183 pupils, 72 of whom were taking the math course, enrolled in Balıkesir Sciences and Arts Center for the 2013/14 academic year. The sample for this study comprised 21 students randomly selected from among the students enrolled at the Balıkesir Sciences and Arts Center in the second semester of the 2013/14 academic year.

The Assessment Tool

As is well known, open-ended questions form many of the problems encountered in everyday life. Such problems are also called ill-structured problems. In terms of tasks, closed-ended problems are well-formulated and well-structured, the correct answer to which can be specified using basic formulae, and the necessary information is provided in the problem statement. Furthermore, the problems with missing information are those where adequate information for a solution is not provided, and the students are required to understand the problem in order to figure out that the given information is insufficient. Another variety of problems adopted by the problem-posing approach is to ask the student to write the proper question after giving her/him the arithmetic operations involved in the solution.

In order to collect data for the study, a test comprising ten questions, which included open- and closed-ended questions, questions with missing information and questions in line with problem-posing approach, was administered to gifted students, specifically to reveal their discernment and creative abilities. The breakdown of the assessment tools is listed below:

1. Closed-ended question,
2. Open-ended question
3. Open-ended question with missing information,
4. Problem-posing for an open-ended question,
5. Open-ended question (with no definite formula),
6. Open-ended question with missing information,
7. Creative problem solving (simplified),
8. Open-ended question (requires creative problem solving skills),
9. A question to be solved with creative problem solving which require estimation and checking (more than one solution),
10. Problem-posing within open-ended question.

Findings

The findings of the study consisted of a classification of the data on problem solving strategies employed by the participants during the test and the answers they provided to the problem-posing approach.

The students were not told about the open-ended questions before the test was administered. In other words, the students were not informed on what kind of strategy they could pursue in order to solve the open-ended questions. Nevertheless, a researcher explained that some of these problems might have more than one correct answer, so each student should write down her/his thoughts on the solution to the problem. In turn, during the test, it was stated that some of the problems might need to be evaluated from a wider perspective in order to find a solution.

The problems answered by the students were assessed within this context.

Findings and Comments on the First Problem

Considering their answers to the question, "*A polar bear is 25 times heavier than Ahmet. If Ahmet weighs 20 kg, what is the weight of the polar bear?*" the students were analyzed in one of three groups (Table 1).

Table 1.

Findings Regarding the First Question

Solution	Number (students)
Correct answer	19
Correct answer using the wrong operation	1
Those who said *"It depends on where it is measured"*	1

Analyzing the answers given, it was observed that a majority of the students succeeded in solving the problem correctly. Moreover, it was impressive to see that there was a student who showed a critical approach even to an closed-end question.

Findings and Comments on the Second Problem

Considering their answers to the question, "*You have two plastic cans, one of which has a volume of 5lt and the other has a volume of 3lt. Using these two plastic cans only, how can you get 4lt of water?*" the students were classified into four groups (Table 2).

Table 2.

Findings Regarding the Second Question

Solution	Number (students)
Those who tried to solve the problem using only arithmetic operations	2
Those who left it blank	6
Those who gave an answer without discernment	11
Those who gave an answer without discernment	2

The solutions of the two students who gave the correct answer are as follows:

• 1. Student: "*We fill the 3lt can twice and discharge it into the 5lt can. There will be 1lt left in the 3lt can. We empty the 5lt can. We pour the content of 3 into 5 lt can. We add another 3. So we will have 1+3.*"

• 2. Student: "*First I would fill the 5lt can completely and pour it into the 3lt can. I discharge the water in the 3lt can, and pour the remaining 2lt into that can. I would refill the 5lt can, and then pour the other which already contains 2lt, then there will be 4lt left."*

Analyzing the answers given to the second question, it can be said that the students who gave an answer to the question without discernment (almost half of the students) ignored the statement "using these two plastic cans only" while trying to solve the problem. For many of them referred to plastics cans that were not given in the question. This could indicate that the students showed a lack of attention while reading and comprehending the question.

Findings and Comments on the Third Question

Considering their answers to the question, "*The sum of Ahmet and Ali ages is 70. How old is Ahmet?*" the students were analyzed in five groups (Table 3).

Table 3.

Findings Regarding the Third Question

Solution	Number (students)
Those who offered a solution based on their individual interpretations	9
Those who offered a solution with algebraic terms	4
Those who offered an arithmetical solution	4
Those who said *"it depends"*	1
Those who left it blank	3

The solutions of students who offered algebraic solutions is as follows:

• *70 - the age of Ali = the age of Ahmet* (the same expression in two students)

• *Ali = x*
70 - x = Ahmet

• *70 - x*

Critical thinking is one of the most important attributes that gifted students should adopt. This is the only way to raise scientifically literate individuals. The new curriculum being applied in primary education is also based on this consideration.

Looking at the answers given to the problem, it can be seen that since being exposed to open-ended question more frequently than in previous years, our gifted students have realized that it is necessary to contemplate and consider the problem from different perspectives before trying to solve it.

Findings and Comments on the Fourth Problem

The students' answers to the question,

"*Write down a proper problem for the mathematical solution,*

51 + 67 + 47 = 165
165 : 3 = 55".

were analyzed in four groups (Table 4).

Table 4.
Findings Regarding the Fourth Problem

Solution	Number (students)
Examples within which the problem was put into a specific context	9
Examples similar to routine exercises	9
Examples that proved the concept of average had not been understood	1
Those who left it blank	2

Examples within which the problem is put into a specific context:

• "*We have bags full of fodder with 51, 67 and 47 kg weights respectively. How many kg of fodder can we give to 3 farmers?*" (even distribution).

• "*A kid got 51, 67 and 47 from his math tests. What is his grade point average?*" (average calculation)

Examples similar to routine exercises:

• "*What is the quotient of the sum of 51, 67 and 47 divided by 3?*" (verbal explanation of the operation)

• "*Ahmet is 51, Ayşe is 67 and Murat is 47 years old. What is arithmetic mean of the sum of their ages?*" (arithmetic mean)

Analyzing the answers given to the problem, it is possible to say that some of the students understood the concept of average, which allowed them to write down creative problems relevant to daily life. It was observed that the amount of routine type examples were large, indicating that even gifted students have difficulties in posing problems, as they get used to solving problems rather than posing them.

Findings and Comments on the Fifth Problem

The students' answers to the question, "*You want to boil your egg exactly for 11 minutes. You have a 9 minute and a 7 minute hourglass. How can you solve this problem?*" were categorized into three groups (Table 5).

Table 5.
Findings Regarding the Fifth Question

Solution	Number (students)
Those who solved the problem correctly	11
Those who gave an answer without discernment	3
Those who left it blank	7

An example of correct solution: "*I start both hourglasses at the same time. When the 7-minute hourglass is empty, I start boiling the egg and when the upper bulb of the 9-minute hourglass is empty, I invert it, and when it is empty again, I turn off the heat.*"

An example of answer without discernment: "*We start the 9-minute hourglass on the 2nd minute of the 7-minute hourglass.*"

Considering the fact that almost half of the students solved the problem correctly, we may conclude that our sample of gifted students could solve open-ended questions. This can be taken as an implication of creative problem solving skills of gifted students.

Findings and Comments on the Sixth Question

Considering their answers to the question, "*A polar bear weighs 500 kg. The total weight of how many children is equal to the weight of the polar bear?*" the students were analyzed in six groups (Table 6).

Table 6.

Findings Regarding the Sixth Question

Solution	Number (students)
Those who did arithmetic operations	8
Those who gave an answer without discernment	6
Those who gave an answer based on algebraic terms	2
Those who reflected on the question by assigning values	1
Those who said "*it depends on the weight of the child*"	1
Those who left it blank	3

It was observed that, assuming that the problem could be solved with arithmetic operations, 14 of the gifted students habitually tried to calculate the weight of the polar bear, based on the weights of children, even though such information was not given in the question.

The solutions of students who offered algebraic solutions were as follows:

- $500/x$
- $500 : x = y$

(*x: average kg*)
(*y: number of children*)

Using algebraic expressions, two gifted students managed to disambiguate the open-ended question with missing information using algebraic thinking.

The student who tried to assign values (1 student):

- "*1 or 2 or 3 or ... 499 or 500*"

1 gifted student disambiguated the uncertainty due to missing information by listing all possible integer values.

Furthermore, pointing out the missing information, another gifted student answered the question as "*It depends on the weight of the child*". This might also be an outcome of analytical thinking.

Findings and Comments on the Seventh Question

Regarding their answers to the question, "*How many squares are there within a large square which consists of 9 smaller squares with 3x3 dimensions?*" the students were analyzed in three groups (Table 7).

Table 7.
Findings Regarding the Seventh Question

Solution	Number (students)
Those who gave the correct answer	17
Those who forgot to count the 3x3 square	3
Those who gave an answer without discernment	1

Even though this was not a tough question, it was important in terms of identifying relationships and creative mathematical thinking. It was observed that these gifted students solved the question correctly using their creative problem solving skills.

Findings and Comments on the Eighth Question

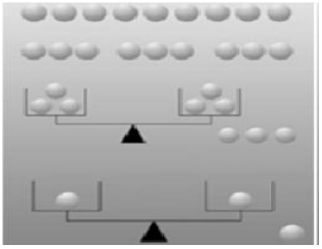

Figure 2.
The Solution Diagram of the Eighth Question

Regarding the question, "*Among 9 marbles of equal volume, one is heavier than the others. Using an equal arm scale, what is the minimum number of weighings required to find the heaviest marble?*" the students' answers were analyzed in four groups (Table 8).

Table 8.
Findings Regarding the Eighth Question

Solution	Number (students)
Those who gave the correct answer	3
Those who gave an answer without discernment	8
Those who said *"I don't know"*	1
Those who left it blank	2
Those who gave a sarcastic answer.	7

There were three gifted students who gave a perfectly correct answer to the eighth question. It was observed that seven students gave sarcastic answers such as "*In the first trial if you are lucky*". Implications of humor in answering an open-

ended question which require creative thinking is remarkable. This is in line with the literature on gifted children.

Findings and Comments on the Ninth Question

According to their answers to the question, "*Fill out the circles below with numbers from one to six. You can use each number only once. Can you ensure that the sum of the numbers on each edge of the triangle is 9?*" the students were allocated into two groups (Table 9).

Table 9.

Findings Regarding the Ninth Question

Solution	Number (students)
Those who gave the correct answer	20
those who left it blank	1

The gifted students managed to solve this problem, which requires estimation and checking (with more than one solution) in creative problem solving, by reading it carefully and after various trials. Actually, these solutions indicate that these students are not unfamiliar with creative problem solving strategies. Although gifted students were not informed about the strategy, they were able to apply it.

Findings and Comments on the Tenth Question

Depending on their answers to the question,

"*Write a suitable problem for the mathematical solution:*

$3x + 30 = 180$

$3x = 150$

$x = 50$",

the students were analyzed in seven groups (Table 10).

Table 10.

Findings Regarding the Tenth Question

Solution	Number (students)
Those who gave an answer without discernment	4
Examples within which the problem was put into a specific context	3
Examples similar to routine exercises	7
Sarcastic answers	1
Those who combine algebraic expression with geometric discipline	1
Those who utilize a scale metaphor	1
Those who left it blank	4

The example of the student who gave a sarcastic answer:

"*Solving the problem '3x+10=180', Ahmet found the solution for x and wrote it down his sheet. What would Ahmet write?*"

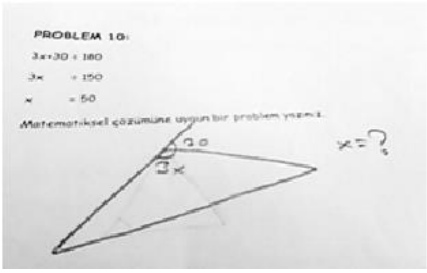

Figure 3.
The Answer that Combined Algebraic Expression with Geometric Discipline

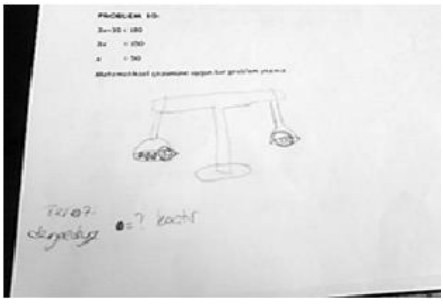

Figure 4.
The Answer that Used the Scale Metaphor

Unfortunately, most of the answers given to this question indicate that our students cannot think outside the box. Majority of the students preferred to transform the problem into the type of problems they are used to. In other words, they did not feel the need to pose the problem in a rather different way. This is, of course, undesirable in terms of critical thinking. The answers given to this question explicitly indicates that individual differences are significant. Developing critical thinking in Turkish schools implies embracing a wide range of perspectives by applying programs differentiated in terms of individual abilities rather than resorting to one-size-fits-all type of policies.

Conclusions and Suggestions

The gifted students who participated in the research study generally gave correct answers to closed-ended questions. They occasionally displayed creative thinking regarding open-ended problems, which do not have a single solution, by making assumptions and interpretations as in real life problems. They gave indications that were in line with the purpose of raising them as inquisitive, questioning, critical and creative individuals. In terms of the non-routine problems, they gave answers containing interdisciplinary relations, with indications of humor to questions that require them to pose problems.

The results of this study points to implications that are in line with the targets of Turkish system of education. It is believed that the individualized instruction applied at Sciences and Arts Centers, within the scope of project based education have contributed to such a result.

On the other hand, textbooks and reference books should incorporate open-ended questions to a greater extent. In order to enhance creative problem solving skills, greater weight should be placed on problem-posing activities. This research study can be repeated at different science and arts centers with a larger sample.

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