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Examining of the non-routine problem-solving skills of prospective science teachers as part of the understand the problem and the solution plan

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Abstract

Today, looking at the goals of the training programs, we are faced with a set of skills called the 21st Century skills. These skills are critically important to success in today's world. One of these skills is to solve the problem and one of the best practices for implementing 21st Century Skills is Problem-Based Learning. However, types of problems referred to here are non-routine problem. In this study, problem-solving skills of the teachers were investigated. For this purpose, a total of 56 prospective science teachers studying in Uludag University have been included in the study. Students were given two different non-routine science problems. The first of the problems has two variables and the second has three variables. Evaluations were made according to Polya's first two steps. Students were asked to write clearly, what they understand from the problem and what should be done in order to find the solution. The data gathered from students was coded and interpreted using descriptive analysis. The findings showed that they were partially successful to solve the two-variables problem, but they failed to solve the three-variables problem.

Keywords: Non routine problem, problem-solving skills, prospective science teachers.

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1. Introduction

When we look at the aims of today's educational programmes, we encounter a series of skills called the 21st century skills. Some of these mentioned skills are defining, formulating a problem and then determining possible solution ways, examining and solving a problem, thinking critically, solving problems, reasoning based on understanding, making complicated choices, making decisions, understanding intersystem relationships, determining and asking questions aiming at clarifying different perspectives and generating more effective solutions, limiting, analyzing and integrating information with the aim of solving a problem and asking questions (Triling & Fadel, 2009). For this reason, problem-solving is one of the important competencies of the 21st century (Joachim Funke, 2014).

According to the literature, we can mention two types of problems, namely routine problems and non-routine problems (Arslan & Altun, 2007; Van de Walle, 1993). The solution of non-routine problems does not only require such mental skills as determining relationships between pieces of data, making analyses and syntheses, thinking in an abstractive and inductive way, looking at a problem from different perspectives, but it also requires performing a series of procedures consecutively (Altun, 2005). Non-routine problems do not have a structure which can be solved via a known method or formula. Solving these problems requires such characteristics as making careful data analyses, having creative experiences, making predictions, controlling, looking for a design, making a systematic list, etc. (Artut &Tarım, 2009). Besides these, a lot of extraordinary problems are defined under the name of real-life problems as well (Cited by Bayezit, 2013). Such problems do not only possess the characteristics of non-routine problems, but they also include some unique conditions resulting from real-life situations with which they are associated.

Having stated that students generally have some problems when they are faced with procedures of solving exercises, they rely on solutions which they already know when they encounter a new problem and, hence, fall short of solving the new problem. Mourtos, Okamoto and Rhee (2004) determined differences between solving problems and solving exercises, gathered them under eight headings and emphasized that a problem should be a real-life problem.

Non-routine problems help to develop students' critical and creative thinking skills (Candelaria & Limjap, 2002) and provide a wide area for various solutions, strategies and approaches to problems. Moreover, they also provide students with a realistic situation in which they can use high-level thinking skills such as practising, synthesizing and creating (Mabilangan, Limjap & Belecina, 2012). As it was stated by Yuan (2013), problems should not only be routine problems, but they should also be problems requiring independence, judgment, authenticity and creativity to some extent.

In the solution of non-routine problems, rather than obtaining the correct answer, thoughts and approaches exhibited in the solution process are important (Mayer, Sims and Tajika, 1995). In other words, not the result but the way of reaching that result is much more important (approaches and strategies used and logical predictions made in relation to the result, etc.) (Bayezit, 2013)

Non-routine problems or real-life problems have a structure in which we start from the known and reach the unknown or the solution. When solving a mathematics or physics problem, processes applied in mind are similar. Therefore, students or individuals not having problem-solving competencies do not become successful in solving problems which they face in real-life either. Studies made in the field of mathematics revealed that one of the reasons why students had difficulty in solving problems was that they could not understand what was asked in the problem (Gokkurt & Soylu, 2013).

According to the PISA 2012 report, “The whole of life in modern societies is solving problems. Changes in the society, environment and technology mean that the content of practical knowledge has rapidly developed. Encouragement to try new things, learning and being prepared to learn via mistakes are always among the keys to resistance and success in an unforeseen world." For these reasons, a new dimension was added to the PISA examinations under the name of “Creative Problem-solving: Students’ Skills in Tackling Real-Life Problems” and today’s employers need elements of having the ability to solve non-routine problems (OECD, 2014). For this reason, in many professional fields, the problem-solving ability is regarded as a requirement of success and problem-solving individuals gain acceptance.

Starting from all these, it can be stated that the education given at school should aim to develop students' problem-solving skills. The duty of teachers is to prepare students for the future with attitudes and skills with which they can solve problems which they may encounter every day (Unsal & Ergin, 2011). For this reason, teachers should pay attention to using developing teaching methods. For, such methods as problem-based learning, research-based learning and individual and group project works can be used to strengthen deep understanding and prepare students to apply their knowledge to new situations (OECD, 2014).

In this study, it was benefited from Polya's strategy, which is known as the most common of the problem-solving strategies. The strategy is composed of four steps, namely understanding the problem, making a solution plan, applying the plan and retroaction or revising the solution. It is observed that the most important step in the problem-solving process is the step of understanding the problem. Gokkurt and Soylu (2013) reached the result that one of the important reasons of failure in problem-solving was that the students did not understand the problem. Again, according to many educationalists, understanding the problem comes in the lead of the factors affecting problem-solving (Cited by Cankoy & Darbaz, 2010). According to Cankoy and Darbaz (2010), an individual who does not understand the problem naturally cannot use an appropriate strategy to solve the problem, solve the problem, cannot explain what s/he does and why s/he does it and even does not spend effort to solve it. For this reason, in the study, the first two steps of Polya's were taken in hand. These steps are:

1. *Understanding the problem:* In this step, the individual restates the problem in his/her own words, figures and graphs. Firstly, s/he puts the problem into a state which s/he can understand. When doing this, for example, such actions as using appropriate symbolic structures belonging to the event or relationships, posing sub-problems might be performed.

2. *Devising a plan for the solution:* In this step, the individual tries to determine the structure of the problem and determines what is given and what is wanted. S/he uses these in the development of solution ways. Here, for example, such actions as using diagrams, figures, graphs, etc., looking for relationships, making predictions, writing open statements, benefiting from solutions of similar problems, reasoning, comparing solution strategies and determining an appropriate solution strategy might be performed.

2. Method

Since this study aims to reveal an existing situation within the scope of "understanding the problem" and "making a solution plan", two of the Polya's problem-solving steps, by investigating the science education preservice teachers' skills of solving non-routine problems, it is a descriptive study. The collected data was evaluated via the content analysis method. In the content analysis, there are four steps, namely processing qualitative data obtained from various materials, coding the data, finding the themes, arranging the codes and themes, defining and interpreting the findings (Yıldırım & Simsek, 2006).

Here, the data which the written materials collected from the students included was evaluated by taking the above-specified problem-solving steps and method into account.

2.1 Sample

56 first year science education preservice teachers taking education at the Education Faculty of Uludag University were included in the study.

2.2 Data Collection Tool

As a data collection tool, two non-routine problems were developed by the researcher and handed out to the students. The students were expected to solve the given problems within a lesson hour by writing them clearly step by step.

2.3 Data Analysis

In this stage, in accordance with Polya's first and second step, a rubric was developed. For example, in accordance with the step of understanding the problem, such steps as "Did the student manage to restate the problem by using figures, diagrams, etc., which s/he had developed by her/himself or through written expression?", "Were the variables determined clearly?", "Is there a piece of information or a plan which is in line with what is given and what is wanted in the step of devising a plan for solution?", were formed and the collected written data was analyzed.

3. Findings

The results belonging to the sequence of procedures established in accordance with the step of understanding the problem, which is Polya's first step, were given for both problems in Table 1.

Table 1. 1st Step Results belonging to the First and the Second Problem (Understanding the problem)

Sequence of procedures	First problem (%)	Second problem (%)
Stating the problem in their own words	96.5	93.0
Demonstrating the event and relationships via appropriate symbolic structures	3.16	33.3
Posing sub-problems	57.9	84.2

The results belonging to the sequence of procedures established in accordance with the step of devising a plan for solution, which is Polya's second step, were given for both problems in Table 2.

Table 2. 2nd Step (Devising a plan) Results belonging to the First and the Second Problems

Sequence of procedures	First problem (%)	Second problem (%)
Using diagrams, figures, graphs, etc.	0.0	1.75
Looking for relationships	61.4	52.6
Making predictions	47.4	46.7
Benefiting from solutions of similar problems	1.75	14.0
Reasoning	50.8	29.8
Comparing solution strategies	5.26	0.0
Determining an appropriate solution strategy	42.1	43.8

4. Conclusion and Discussion

The preservice teachers were given the following problems.

Problem 1: "A student wonders how an object moves in water, olive oil and honey and wants to investigate in which liquid the object moves faster. For this purpose, write clearly what the student is supposed to do?"

Problem 2: "A sponge producer wants to research into the relationships between the volume, bore diameter and water absorption capacity of the sponge which s/he produces. For this purpose, write clearly what s/he is supposed to do?"

As it is seen in Table 1, the procedure of restating the problem belonging to Polya's first step in their own words is a procedure which is carried out by the preservice teachers successfully. For both problems, a great majority of the students restated the problem in a way that they could understand it better through writing small explanations, notes belonging to the problem.

However, in the procedure of demonstrating the event and relationships via appropriate symbolic structures, for example, expressing via tables, graphs, figures, numerical relationships, while the students remained at the level of 3.16% in the first problem, this rate increased to 33.3% in the second problem. Of course, the contents of the problems are important in this result. While the first problem contained a result dependent on two variables, the second problem had a structure which required the students to find a statement dependent on three variables.

In the realization of posing sub-problems, a result of 57.9% was obtained for the first problem and a result of 84.2% was obtained for the second problem. Here, the students divided the problem into parts and used symbols or verbal expressions when performing this procedure. For example, for the first problem, they used such expressions as "Three objects with the same volume or mass must be taken" or "first of all, we must know the densities of water, olive oil and honey". Moreover, for the second problem, they used such expressions as "It is necessary to examine if the bore diameter of the sponge changes according to its volume." or "First of all, we keep the volume constant and look at the relationship between bore diameter and water absorption capacity." For this procedure, it can be considered that the students became successful especially in the second problem. According to Jäkel and Schreiber (2013), when dealing with new or difficult problems which cannot be solved via standard methods, good problem solvers perform their introspections, specify their strategies and ideas, evaluate their progress and reveal if they have managed to solve the problem or not.

The results belonging to the procedure of devising a plan for solution, which is the second step of Polya's, were given in Table 2.

The results belonging to the procedure of using diagrams, figures, graphs, etc. are rather low for both problems. We observe that our students do not generally have the skills or habits of using these tools when solving problems. We can describe the procedure of looking for a relationship as determining variables and interpreting or accounting for relationships between variables. According to this, it can be stated that the students showed an average level of success for both problems. For the procedure of making predictions, the results were observed to be nearly similar to both problems. The results belonging to the procedure of benefiting from solutions of similar problems were very low for both problems. This result can be normal because the students stated not having encountered such kinds of problems very frequently and had difficulty solving them. The reason for the small increase observed in the second problem might be the examination of a problem in a similar structure in laboratory lessons. We also observe that the procedure of reasoning had a higher value for the first problem. Again, this result might have resulted from the simpler structure of the first problem. The procedure of comparing solution strategies was not observed for both problems. We can conclude that our students' skills of thinking in different ways, searching or proposing have not developed sufficiently. On the other hand, the procedure of determining an appropriate solution strategy was again at the equal level for both problems.

When we evaluate these obtained results in general, we can state that our students' non-routine problem-solving skills had not developed sufficiently at both steps of Polya's. As possible reasons for these results, we can state that our students had encountered mostly routine problems in their previous educational lives, developed certain solution patterns and had difficulty getting out of these patterns. In a study with mathematics preservice teachers, Dundar and Yaman(2015) reached similar results. The authors stated that the preservice teachers could not solve the problem correctly or incorrectly because the essential problem underlay the step of understanding the problem. In a study with engineering students, Mourtos, Okamoto and Rhee (2004) reached the result that the engineering students encountered too many routine problems and, for this reason, experienced failure when they encountered daily life problems. In a study carried out with the classroom preservice teachers and investigating the preservice teachers' success levels in relation to the routine and real-life problems, Bal (2015) reached the result that the students were successful in solving routine problems, but they were unsuccessful in solving real-life problems and explained the reasons of this result by stating that solving a real-life problem requires upper-level thinking skills and student do not encounter such kinds of problems very often.

For this reason, as it was stated in the OECD 2014 reports, it is essential for our students and for the future of our country that problem-solving skills, which have become very important today, should be attached necessary importance especially when solving non-routine or daily life problems, included in almost every lesson in school programs, our teachers should be aware towards and knowledgeable of this matter.

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