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Investigation of the Approaches Used by the Science Teacher Candidates in Solving the Real-world Chemistry Problems

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Abstract In this age of science, there is a need for rational individuals who are open to innovations to be able to limit and combine information and establish inter-system relationships. Problem solving is considered to be the most important cognitive activity that requires mental effort and will-power. The processes applied in mind when solving a mathematical and chemistry problems are similar. This study was conducted with a total of 50 students studying in the first grade of science teacher education. Two different chemistry problems, which are not routinely given to students, are being investigated and the approaches that science teacher candidates exhibit in solving real-life chemistry problems are desired. It is a descriptive research since an attempt has been made to demonstrate an existing situation in the study. According to the findings, it is seen that most of the candidate teachers are successful in expressing both problems in their own way, but they are less successful in expressing the chemistry knowledge necessary to solve the problem and relating them to the solution.

Keywords Real-world Problems, Problem Solving, Prospective Science Teachers

1. Introduction

When the objectives of the education programs are examined, we are faced with a series of skills. One of these skills is problem solving. According to [1], problem solving is considered to be the most important cognitive activity that requires mental effort and endeavor. According to [2], the existence of a problem is defined by the fact that the knowledge and thought of the problem solver fail to overlap with the situation encountered and the distortion of the cognitive balance in the individual. While the problem is a static situation, problem solving is defined as a dynamic process in which mental activities are carried out [3]. In this process, the individuals understand the problem, develop and apply methods and strategies and try different solutions. Developing appropriate strategies and using them in order to solve problems that are relevant to everyday life are among the basic benefits that students should acquire in this field.

It is possible to classify the problems in two groups as routine and non-routine problems [4, 5]. Routine problems can be solved by applying the known rules, formulas and methods. The solution of non-routine problems, on the other hand, requires the ability to perform a series of operations as well as mental skills such as determining associations between data, being able to analyze and synthesize, being able to think in abstract and inductive way and considering problems from different perspectives [6]. Non-routine problems are not in a position to be solved by a known method or formulation. To be able solve these problems requires such characteristics as careful data analysis, creative experiences, making estimations, examination, searching for patterns, and making a systematic list [7].

Apart from this, some real-world problems are described under the name of unusual problems (cited in [8]). These kinds of problems include not only the characteristics of non-routine problems, but also a number of specific conditions that emerge from the real-life situations which they relate to. It is necessary to make use of the existing experiences and intuitions that are relevant to the real life of the students in order to overcome the cognitive conflicts and uncertainty that real-life problems can create in their minds [9]. The solution of real-life problems requires the ability to transfer knowledge to real life, develop and use original strategies and models, be able to make reasonable estimates of solutions, and evaluate the accuracy of the result obtained within the real-life context [10].

Studies on real-life problems in different age groups in different countries such as Japan, England, Belgium and

Sweden revealed quite similar findings [10-14]. Findings demonstrated that when solving real life problems, students did not take into account the knowledge related to real-life in the problem story, they had difficulties in transferring mathematical knowledge and thoughts to real life and they did not benefit from intuitive knowledge and experiences regarding the daily life [8]. There are also study results that show that the difficulties in solving the real-life problems and the unrealistic approaches are common among the teacher candidates [15].

When the studies on the problem solving in Turkey are examined, it was found that most of them were the routine problem-solving skills of elementary school primary school students and fewer studies aimed at solving non-routine problems [16-18]. On the other hand, it is clear that there are some deficiencies in the studies that address real life problems [8]. However, it was stated that real-life problems provided appropriate learning-teaching environments for students in order to gain important cognitive abilities such as the development of critical and creative thinking, developing and using original approaches and methods and adapting knowledge and applying them in different environments [19].

In the industrial societies, the human model that is capable of taking rapid action is replaced by the problem-solving human model. For this reason, problem-solving skills today have significantly increased the importance of advanced humans. In order to be able to find answers to the questions in an age considered as the age of science, intelligent individuals who are open to innovations, able to limit knowledge, able to combine it, and able to establish inter-system associations are needed. The processes applied in one's mind when solving a mathematics, physics or chemistry problem are similar. Nowadays, as solving real-world problems gained importance in work and one's everyday life. It has become one the major capabilities people can have in twenty-first century. For this reason, the aim of the present study was to investigate the approaches that science teacher candidates exhibited in solving real-life chemistry and physics problems. In this study, answers to the following research problems were sought:

1. What are the competences of science teacher candidates to understand the real-life problems?
2. To what extent do science teacher candidates make use of knowledge of chemistry in solving real-life problems?
3. Are science teachers able to suggest logical solutions by using accurate knowledge of chemistry while solving real life problems?

2. Materials and Methods

In this study, where the aim was to examine the approaches that science teacher candidates used in order to solve real life chemistry problem, the teacher candidates were given two daily life problems and their solutions were analyzed. Since an attempt was made to establish an existing situation in the study, it is a descriptive research. The data collected were evaluated using the content analysis method. In content analysis, there are four stages: processing of the qualitative data obtained from various materials, coding them, finding the themes, arranging the codes and themes, identifying and interpreting the findings [20]. In the present study, the data included in the written materials collected from the students were evaluated taking into account the above-mentioned method.

2.1. Sample

50 freshman level science teacher candidates studying at the Faculty of Education of Uludağ University were included in the study. The real-world problems used in the study were created by using freshman chemistry curriculum. For this reason, the study sample was only including freshman level teacher candidates. The teacher candidates were identified by a simple random sampling method. In this type of sample selection, each individual in the population has an equal chance to be selected for the sample group [21].

2.2. Data Collection Tool

Two non-routine real-life chemistry problems were developed by the researcher as data collection tools and the problems prepared were presented to two experts who were experienced fieldworkers and then they were applied after the necessary corrections were made on the problems concerning language and contextual aspects. The forms in which non-routine problems were included were distributed to the teacher candidates and they were expected to solve the given problems step by step in one lesson-hour period. The problems available in the relevant form are explicated below.

Problem 1: One student was surprised to see that citrus growers led the water to freeze by spraying water over the citrus fruits in the winter months. The student who was very curious about the cause of this situation wanted to investigate this issue. Please write down clearly what the student needs to do for this purpose.

Problem 2: Another student, after realizing that even though a glass of water evaporated and diminished in a few days, wanted to investigate how honey and boiled grape juice could stay in a container for a long time without drying. Please write down clearly what the student needs to do for this purpose.

2.3. Data Analysis

In the present study, the data obtained from the problem solutions of teacher candidates were analyzed according to

the themes of understanding the real-life problem, recognizing the chemistry in life and using the knowledge correctly in solving the problem. Content analysis method was used in the analysis of the data, [22, 23]. In the analysis process, initially the ideas and approaches used to solve each problem were converted into short codes. In the process of coding the data, the data were evaluated several times and worked on and opinions were obtained from expert fellow faculty members.

In the subsequent stages, the codes generated continued to be examined, and the statements containing similar thoughts and approaches were collected under more general categories.

The theme of understanding the real-life problem associated with the first problem sentence of the study; the ability of the science teacher candidates to express the problem with their own words, figures and graphics, and their ability to demonstrate the events and associations with appropriate symbolic structures were investigated. At the end of these analyses, the categories created were grouped under three main headings. These headings were: Understanding the problem completely: Understanding the problem incompletely and: Failure to understand the problem. According to these criteria, the following groups were generated; complete comprehension included statements, figures, graphics with serious clues and indications that the knowledge and situations given by the teacher candidates were understood and taken into consideration completely; incomplete comprehension included a lack of sufficient clues for them; and failure to understand included those that lacked them.

The analysis of this theme is similar to the first step of Polya's strategy of understanding the problem, which is one of the most commonly known problem-solving strategies. In this step, the individual expresses the problem again in his / her own words and own figures and graphics. Firstly, the problem is converted into in a form s/he can understand. In doing so, for example, acts such as using appropriate symbolic structures related to events and associations and creating sub-problems (Cited in [24]). An individual who fail to understand the problem naturally cannot use an appropriate strategy to solve the problem, cannot solve the problem, cannot explain what and why s/he has done it, and does not even try to solve the problem [25].

Another objective of the study is the question of the extent to which the science teacher candidates utilize chemistry knowledge in solving real-life problems. With the theme of recognizing the benefits of chemistry in real life associated with this question, the concepts, formulas, figures, diagrams and graphics related to chemistry were examined. At the end of the analyses, the categories created were grouped under three main headings. These headings were; successful use of chemistry knowledge, incomplete knowledge of chemistry, and failure to use the knowledge of chemistry. According to these criteria, the following groups were generated; use of chemistry knowledge by the teacher candidates included statements, figures, graphics containing chemistry knowledge; a lack of sufficient chemistry knowledge to solve problems and incomplete use of chemistry knowledge; and failure to use the chemistry knowledge included those that lacked them. According to the relevant literature, it is commonly known that mathematical models (figures, diagrams and graphics) generated by drawing to solve mathematics-related problems are considered as problem solving strategies [26, 27]. In addition, the visual objects, which could be substituted for the real-life situation associated with the problem with their ability to represent the real-life conditions for their visual properties and meanings were also used in solving problems [28]. Apart from these, experiments are also often used to solve science-related problems [29].

Finally, we examined the accurate use of knowledge to solve the problem and recommend logical solutions with the help of relevant knowledge. According to these examinations, the categories were grouped under two headings. These headings were: using the knowledge accurately and using the knowledge inaccurately. According to these criteria, when the problem was solved by explaining the appropriate chemistry concepts and principles, using the examples and formulas relevant for the subject and the case of recommending experiments was regarded as the accurate use of knowledge; insufficient chemistry knowledge as the inaccurate use of the knowledge; and problem solving done based on erroneous knowledge as the incomplete use of knowledge.

2.4. Validity and Reliability

In order to verify the internal validity of the study, a specialist examination was resorted to and in the presentation part of the findings, a direct quotation of the written statements of the teacher candidates regarding the themes was made and the extreme generalizations were avoided, taking into account that the interpretations made by the teacher candidates were limited to these citations. Moreover, every step has been clearly indicated.

3. Results

Table 1 shows the results obtained for the two problems of the sequence of operations created according to the theme of real life problem understanding.

Table 1. Results of real life problem understanding of the first and second problem

Operations sequence	The first problem (%)	The second problem (%)	Categories	Theme
State the problem in their own words	90 6 4	92 4 4	Full comprehension Partial comprehension No comprehension	Understanding of the problem
Show events and associations with appropriate symbolic structures	20 6 2	30 8 2	Full comprehension Partial comprehension No comprehension	
Establish sub problems	70 10 2	80 8 4	Full comprehension Partial comprehension No comprehension	

As it is seen in Table 1, the process of rephrasing the problem in their own words has been successfully made by the prospective teachers. The vast majority of candidates have expressed the problem in their own way by writing notes, and probing in both problems.

In the process of expressing events and relations with appropriate symbolic structures such as tables, graphs, figures, numerical relations, students stay at the level of 20% in the first problem and 30% in the second problem. Of course, the content of the problem is also important in the result.

The results for forming sub-problems for the first problem and the second problem are 70% and 80%, respectively. The students have divided the problem into parts and used symbols or verbal expressions while doing it.

For example, some citations from the teacher candidates' own statements and forms for the first problem are given below:

"Firstly, the freezing point of pure liquid and of solution should be known"

"The influence of concentration on the freezing point should be known"

"The variety of citrus must be known as the freezing point will decrease according to the amount of dissolved substance (sugar) in the citrus"

"It should be known that the freezing event is an exothermic event"

"During freezing, water gives heat to orange and keeps the temperature constant."

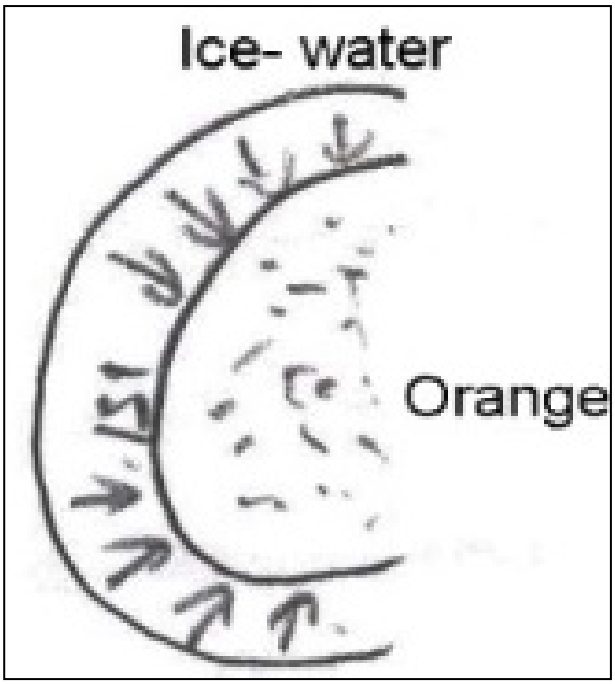
For the second problem, some quotes from prospective teachers' own statements are given below:

"It is necessary to examine whether the evaporation depends on the structure of the material."

"The relationship between intermolecular attraction forces and evaporation must be investigated."

"The temperature must be kept constant and other conditions affecting evaporation must be investigated.

"Pure liquid is easy to evaporate; however, other substances that dissolve in pure liquid delay evaporation.



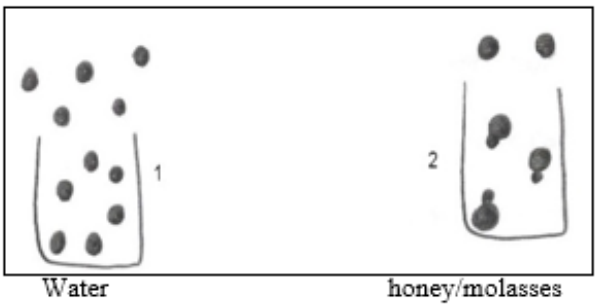


Table 2. An analysis of the first problem: awareness of chemistry in life

Codes	The first problem (%)	Categories	Theme
* Water cooling is an exothermic reaction. * Protective measures should be taken if the temperature falls below 0°C. * Manufacturers should protect lemon more than orange. * Dissolved material in fruit juice reduces the freezing rate by 1.2°C. * As the concentration increases, the freezing point drops. * Decrease in freezing point depends on molar fraction of solubility. (ΔT_d= -K_d x m) * Salting of roads in winter is also an example of freezing point descent.	40 10 8 40 60 10 10	Good use chemistry knowledge	Awareness of chemistry in life
* Water freezes at 0°C. * The freezing point of each item is different.	10 10	Incomplete use of chemistry knowledge	
* Citrus should be grown under the climatic conditions where the temperature of the air is appropriate. * Citrus need a lot of water.	8 6	No use of chemistry knowledge	

Table 3. Analysis of the recognition of the chemistry in life for the second question

Codes	The second question (%)	Categories	Theme
* The viscosities of the three materials are different from each other as well as their evaporation features. * The attractive forces between the molecules affect evaporation. * The vapor pressure is determined by $P_A= x_A.P^0_A$ (Raoult's law). * Evaporation becomes more difficult as the concentration increases.	60 20 6 70	Good use chemistry knowledge	Awareness of chemistry in life
* Evaporation occurs at every temperature. * Honey and molasses are not volatile. * Water is a liquid that evaporates easily.	10 6 10	Incomplete use of chemistry knowledge	
* There is pressure difference. * Honey and molasses are low in water. * Water is in glass but honey and molasses are not.	8 4 2	No use of chemistry knowledge	

In the study, the results of examining the use of information in problem solving and suggesting logical solutions with the help of information are given in Table 4 and Table 5 for both problems

Table 4. Analysis of correct usage of the information given for the solution in the first problem

Codes	The first problem (%)	Categories	Theme
* Freezing is an exothermic reaction. The water sprayed on the citrus fruits gives heat during freezing so that the temperature remains constant and the citrus fruits are protected from being frozen. * As the soluble materials in the fruit reduce the freezing point, the fruit does not freeze in the temperature that the water is frozen. * If we define according to the formula ΔT_d= -$K_d$xm, then the value of K_d. in the line is bigger than water. As the K_d value increases, the freezing point drops. * Freezing points are reduced by sprinkling salt on roads in winter.	40 40 10 10	Correct use of information	Using the information correctly to solve the problem
* The concentration of citrus fruit is high, so the freezing point is low. When we dilute it by spraying water, the freezing point rises. * Citrus has crusted, porous structure. It is frozen on purpose to protect it from microbes. * Spreading salt in the winter and freezing the citrus fruit is not the same.	6 4 2	Wrong use of information	

Table 5. Analysis of correct usage of the information given for the solution in the second problem

Codes	The second problem (%)	Categories	Theme
* $P_A = x_A.P^0_A$ (Raoult law) educes the vapor pressure of a dissolved solvent according to the law. For that reason, honey and molasses are not easily evaporated unlike water even though they are on the same conditions.	6	Correct use of information	Using the information correctly to solve the problem
* Pure liquid is easy to evaporate; however, other substances that dissolve in pure liquid delay evaporation, therefore honey and molasses do not evaporate.	40		
* Water molecules of honey and molasses have different interactions between molecules. For this reason, viscosities and evaporation rates are different.	10		
* The greatness of viscosity means that molecules keep each other very strong. Honey and molasses do not evaporate easily like water.	60		
* Evaporation occurs at every temperature. We can observe evaporation in all three if we increase the temperature.	4	Wrong use of information	
* It is related to vapor pressure. Because honey and molasses are dense, they do not trade energy with air.	2		

4. Conclusions

Both problems were solved by using the first step of Polya's strategy of understanding the problem, one of the problem-solving strategies. In this step, the process of stating the problem with their own words was a process, as seen in Table-1, which was successfully accomplished by teacher candidates. Majority of the students stated the problem in the way they understood it by writing small explanations and notes regarding the problem for both problems.

The process of illustrating events and associations with appropriate symbolic structures, such as tables, graphics, figures, numerical associations, on the other hand, the science teacher candidates were not as successful as the step of stating the problem with their own words. Even though the content of the problem was very important in stating events and associations with tables, graphics, figures, numerical relations, the data obtained for both problems was very low.

In the process of establishing the sub-problems, teacher candidates divided the problem into pieces and used symbols or verbal statements in this process. It is possible to think that the students at this stage were successful in both problems. For instance, the following examples can be given by making citations from the students' statements for the first problem: “First of all, the freezing point of pure liquid and the freezing point of solution should be known”, “The influence of concentration on the freezing point of should be known”, “The variety of citrus should be known, as the freezing point will diminish according to the amount of dissolved substance (sugar) in the citrus”. For the second problem, the following examples can be given: “It is necessary to examine whether the evaporation depends on the texture of the material”, “Intermolecular gravitational forces and evaporation associations should be investigated”, “The temperature should be kept constant and other conditions affecting evaporation should be investigated”. According to [30], good problem solvers introspect while dealing with new or challenging problems that cannot be solved by standard methods; they identify their strategies and ideas, assess their progress, and demonstrate whether they can solve the problem.

The results of the sequence of processes based on the theme of recognizing chemistry in life for both problems are given in Table 2 and Table 3. Some of the teacher candidates attempted to use the formulas, principles and concepts they learned in chemistry to solve problems.

For instance, for the first problem, the following statements illustrate that they wished to relate the knowledge they learnt in chemistry lessons to the event stated in this problem: “Water freezing is an exothermic reaction”, “Protective measures should be taken if the temperature falls below 0^0C”, “Dissolved substances in fruit juice reduces the freezing point by 1-2^{0}C”, “As the concentration increases, the freezing point decreases”, “The decrease in freezing point depends on the mole fraction of the dissolved substances”, ”$\Delta T_d = -K_d \times m$”, “Salting the roads in winter is also an example of freezing point decrease”.

For the solution of the first problem; the teacher candidates are expected to predict that water would generate heat during the freezing process, that is, an exothermic reaction took place and this enabled the temperature to remain constant at 0^0C, so that the citrus juice that had the freezing point at the lower temperature could thus be prevented from freezing. However, the number of teacher candidates who wrote down the whole of the chemistry knowledge required for the solution of a problem was very small, and in general, only few of the statements needed to solve the problem were written down. Some teacher candidates failed to associate the general chemistry knowledge such as “Water freezes at 0^0C”, “Each substance has a different freezing point” with the problems even though they wrote them down.

For the second problem, the following statements indicate that they wished to relate the knowledge they learnt in chemistry classes to the problem; “The viscosities of the three substances are different from each other”, “Gravitational forces between the molecules affect evaporation”, “The vapor pressure is determined by P_A=

$x_A.P^0_A$ (Raoult's law).", "Evaporation becomes more difficult as the concentration increases." The number of teacher candidates who wrote down the all statements of chemistry knowledge necessary for the solution of the second problem was very small. Even though some teacher candidates wrote down the general chemistry knowledge such as "Evaporation occurs at every temperature", "Water is liquid that evaporates easily", they failed to associate them problems in an away. The small increase in association in the second problem with the chemistry knowledge may be due to the fact that the problem was one that was related with the daily life and due to the simpler structure of the problem.

The results regarding the examining the use of knowledge for the solution of the problem and suggesting logical solutions with the help of knowledge for both problems are given in Table-4 and Table-5. As illustrated in Tables 4 and 5, not many solutions for both problems were proposed. It is possible to conclude that the teacher candidates failed to develop skills in thinking, searching or proposing different solutions. While benefiting the solution of similar problems was slightly higher for the first problem, it was never used for the second problem. In the first problem, while the statement "the freezing point is decreased by sprinkling salt on the roads in winter" was perceived as a similar problem, there were no examples of other similar problem statements. Furthermore, the number of participants who proposed solutions by using the formulas and equations they learned in chemistry for both problems was very small. Apart from that, it was observed that for the solution of the second problem, which contained knowledge and ideas that they were more familiar with from the daily life, the teacher candidates were able to realize quickly the original conditions arising from the real life and suggest more realistic solutions.

When we evaluate these results in general, it is possible to say that the non-routine problem-solving skills of the teacher candidates as successful as desired. The reasons for these results are that the teacher candidates generally encountered routine problems in their previous teaching experiences and that they developed certain patterns for the solution of these problems and cannot go beyond those patterns. In [24] study in which science teacher candidates' skills to solve non-routine physics problems were analyzed, it was found that while the teacher candidates were partially successful in solving the two variable problems, they were unsuccessful in solving three variable problems. In their study they carried out with mathematics teacher candidates, [31] also found that the teacher candidates were unsuccessful in solving non-routine problems. In their study they carried out with engineer candidates, [32] concluded that students encountered too many routine problems and thus failed to solve the when they encountered daily life problems. It was observed that in the study in which the approaches the elementary students exhibited in solving the real-life problems and the strategies and models they used were investigated, the students failed to take into consideration the real life conditions related to the problem and tried to reach the result by applying the rules and associations they brought from the past instead of using the knowledge and experience in this field [8].

In another study in which classroom teacher candidates' success of routine and real-life problems were investigated, it was concluded that the candidates were successful in solving routine problems but they were unsuccessful in solving real life problems and it was stated that the reason of this particular result was that solving real life problem required higher level thinking skills and the students rarely encountered such problems [33].

Exposing students to non-routine or real-life problems can improve their reasoning power, as well as their ability to use critical and creative thinking skills. Consequently, attaching importance to problem solving skills, especially for the solution of non-routine or daily life problems that has become a very important skill in this day and age, the fact that these skills are present in almost every lesson in school programs, and that our teachers are sensitive and knowledgeable about the problem solving skills are crucially significant for our students and the future of our country.

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