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Pre-Service Science Teachers' Skills to Express The Algorithms Used in Solving Physics Problems with Flowcharts (An Example From Turkey)

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ABSTRACT

Due to the nature of physics, problem-solving strategies are applied in some cases to teach many subjects. Problem-solving is a process that individuals use, not only in physics classes but also in every stage of life. An algorithm is a pathway to solving a problem or achieving a specific purpose. The purpose of this study is to identify how pre-service science teachers express the algorithms they utilize in the process of solving physics problems. The research design of the study was determined as survey design which is one of the quantitative research methods. The study was carried out with the number of 34 pre-service science teachers consisting of 1st and 3rd-year university students who took General Physics I and General Physics Lab I courses in the undergraduate program in science education at a state university. They were given three problems regarding classical mechanics and then asked to solve these problems and schematize their algorithms by using flowcharts. The International System of Units (SI) was used throughout the research. An evaluation was made by comparing the 3 algorithms of the solution, whose reliability and validity was ensured, and which was previously created with the help of 3 experts. In the study, descriptive survey model was used. Frequency tables were frequently used in the analysis of the data with the intent to present the study in the best way by doing an in-depth analysis. In the findings of the research, it was observed that pre-service science teachers had problems in expressing their algorithms and some of them could not express these algorithms at all. It was also observed that pre-service science teachers had difficulty describing the solutions they created while setting up the problem. However, it was observed that pre-service science teachers who could illustrate their algorithms well were usually the ones who solved the problems correctly.

Keywords: Algorithm; Flowcharts; Mathematics Education; Physics Education; Problem Solving

INTRODUCTION

Physics is a science which is based on the purpose of understanding and exploring nature. In this respect, it can consist of a whole set of questions and the processes of seeking answers to questions, an attempt to reveal the cause and effect relationship and to transfer it to other fields in some cases. Physicists go through some challenging processes in asking questions and finding answers. Due to the nature of physics, one could encounter many problems and come up with problem-solving strategies in physics courses. Although problem solving strategies are often used in mathematics education both in the world and in Turkey, they have vital importance in physics education and need to be developed and updated in different perspectives (Gunduz, 2008; Singh, 2009). Ertek, Ertek and Gunes (2013) have clearly represented the importance of problem-solving strategies directly related to PISA (Programme for International Student Assessment) in Turkey. One of the areas that students are most challenged in physics education in Turkey is problem solving (Toksoy-Eryilmaz & Akdeniz, 2017).

There are 818 theses scanned under the heading "problem solving" in the National Thesis Center in Turkey (Turkish National Thesis Center [YOK], 2019). Of these theses, 543 of them are listed under the title "Education and Training" while 13 of them are listed under the title "Mathematics" and 1 of them is listed under the title "Physics" (In other theses, the majority of studies are in Psychology (11.4%) and secondly in nursing (5.7%). The science studies in-

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cluding education (Science Education, Physics Education, Math Education etc.) can also be listed under the title "Education and Training". This situation is described in Figure 1.

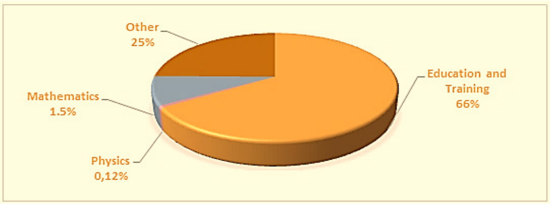

Figure 1. Percentage distribution of researches in the field of problem solving between 1990-2018 at the National Thesis Center in Turkey (Accessed on 15 February 2019).

Figure 1 illustrates that "problem solving" in Turkey is directly connected to the education and training processes, and it is the most needed area in this field. Today, it is indicated that different problem-solving practices have emerged in different disciplines. It is regarded as *"scientific method*" in science, "*creative thought"* in Psychology, *"analytical thought"* in engineering, "*Polya's method"* in Mathematics, and "*creative problem solving"* in other fields (Bozan, 2008). Although this viewpoint is a general and practical classification, problem solving strategies may vary from field to field, from subject to subject (Ozcan, 2011), from individual to individual (Sahin, 2015), from teacher to teacher and from problem to problem (Eryilmaz & Akdeniz, 2013). Problem solving strategies can be classical, modern, and completely unscientific or repeated over and over again in some cases. In addition to this uncertainty about problem solving strategies, there are various opinions and different orientations. There are also several studies in physics education in Turkey that examine problem solving strategies from different perspectives (Bademci & Sari, 2014; Inac & Tuksal, 2019; Toksoy-Eryilmaz & Caliskan, 2015).

According to Bozan (2008), the processes that occur in the teaching of problem solutions in each field are divided into categories; *pedagogical* and *methodical strategies*. Pedagogical strategies include teacher-centered motivation and attention, whereas methodological strategies consist of two main student-centered methods; *algorithmic* and *heuristic*. While heuristic methods involve creative processes, there are widespread views that algorithmic processes involve traditional and procedural processes (Dufresne, Gerace, & Leonard, 1997; Etkina e*t al*., 2006). Algorithms are a sub-step of the problem-solving method (Erkaper, 2007; Sahin, 2015).

Erkaper (2007) asserts that problem solving is an essential behavior that is required to be gained in science courses. The sub-steps of the problem-solving method to be acquired are as follows:

"Finding the necessary principle for the solution"
"Factual knowledge, concept principles, rules, principles etc. using combination"
"Using formulas and algorithms"
"Using and converting units"
"Finding the numerical result of the problem"

The word "algorithm" in Turkish is parallel with the word *"algorithme"* in French that means "the process of eliminating a problem by step-by-step implementation of well-defined rules and procedures or achieving a result as quickly as possible." The algorithm is similar to the word algorithm in English, meaning" a well-defined, finite set of rules for solving a problem, in the form of "a finite number of steps", "solution path", or "chain of operations" (Turk Dil Kurumu [TDK], 2019). Algorithms, like puzzles, consist of a series of previously known and delimited, known series of some operations. The most logical solution can be reached by following the stages of a correctly developed algorithm (Aytekin, Cakır-Sonmez, Yucel, & Kulaozu, 2018). It can be created with various techniques according to the difference of the subject and different needs. Algorithms are practical flows created by generating solutions for problems. It can be transferred to another area.

In this study, the algorithm which is used to simplify a complex algorithm, and which is used to design the algorithm is formed at the most basic level like the top-down technique. The top-down approach for designing algorithms is a technique that allows the designer to handle a complicated algorithm in a simple way (Dershem, 1981). In this approach, flowcharts are created by dividing algorithms. When it is considered that the solution reaches the appropriate level, the process is completed, and it is terminated. Repetitions can be from top to bottom just like they are within the step. Repetitions performed are meant to improve and achieve a better outcome (Dershem, 1981). The processing steps are predetermined. An element of the top-down algorithm consists of formulating and replacing variables. These variables can also be designed to lead to different results in different questions. The process proceeds more automatically. The fact that a problem has been previously shown in a flowchart can be described as a measure to reduce the margin of error (Dershem, 1981). In Figure 2, an example of a top-down algorithm is illustrated.

When the literature is reviewed, it is stated that in solving the problems in physics, from the past to the present, a path is taken from traditional perspectives to creative perspectives. Dufresne *et al*. (1997), reported that some problem-solving strategies found in physics are still a product of algorithmic and procedural processes and they criticized it. According to this critique, the problems solved in physics lessons are no more than the explanation of some ideas in textbooks, the students' repetition of formulas and the conclusion of the problems by following a certain chain of operations and applying this to other problems. In this context, algorithmic processes are inadequate, traditional and need to be developed in terms of comprehending the concepts in depth in the problem-solving strategy or obtaining healthy problem-solving skills (Dufresne *et al.,* 1997; Etkina *et al.,* 2006; Yaman & Yalcin, 2005). According to different perspectives, the algorithms used to solve the physics problems have a practicality in solving the problem and the structure that accelerates the process of transferring the learned knowledge to other areas, but the studies based on this view are relatively fewer than the previous view.

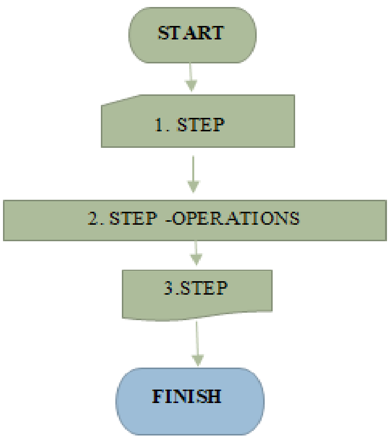

Figure 2. Top-down algorithm approach

In Turkey, comprehensive research on the use of algorithms which is one of the substeps of problem solving in physics education is almost nonexistent. With this study, it is aimed to contribute to the physics education literature and to mirror the current situation in terms of subsequent researches and present an interdisciplinary research. With 3 determined classical mechanics problems, it is aimed to illustrate the ways of pre-service science teachers' problem-solving skills with flowcharts. Of course, the purpose of the study is not only to review the literature on the subject and to lead the way for further research but also to reach the correct results of pre-service science teachers by using the algorithm. In the scope of this study unit's investigation, which Polya (1988) deemed necessary, was also carried out.

In line with the above explanations, the purpose of this study is to identify the ways in which pre-service science teachers express the algorithms they utilize in the process of solving physics problems

METHOD

Research Design

Quantitative research method was preferred for this study. Research design of the study was determined as survey design.The purpose of survey research is usually to describe the situation that exists in relation to the subject of research (Buyukozturk, Cakmak, Akgun, Karadeniz, & Demirel, 2018). At the end of the survey type research, it is important to give the frequencies of the answers to the problems to show the views of the participants. In this research, percentage distributions and frequencies of the answers to the problems are given in accordance with the research method.

Study Group

The study group consisted of a total of 34 pre-service science teachers who were studying in the Department of Science Teaching at a State University in Istanbul in the 2012-2013 academic year and who took General Physics I and General Physics Lab I courses. Of the 34 teacher pre-service science teachers, 4 were male and 30 were female students.

Data Collection Tools

In this study, three types of problems which were frequently found in university physics books (Serway & Beichner, 2014), and that spontaneously had algorithmic processes and algorithmic program structure, were appointed by the experts. These problems were chosen in the field of mechanics. During the selection of the problem subjects, the readiness levels of the pre-service science teachers were taken into consideration. The problems were examined based on the literature regarding whether they had structures that would lead to any misconceptions (Gunes, 2017; Yagbasan, 2005). After selecting the problems, 3 real solution algorithms were developed for the solutions. The visuals in the problems were drawn with the help of a graphic designer in the InDesign CS5 program. It took 2 weeks to prepare this inventory including problems and solutions. After the inventory was prepared, 3 expert opinions were sought for validity studies. After 85% compliance, the missing points in the inventory were developed and arranged and finalized in the 3rd week. Before the inventory was distributed to the subjects, some guidelines were added. These were security measures that provided information about the process of solving the inventory such as notifying that the applications would not be evaluated as a course grade, not having any time limit while completing, emphasizing the individual differences in order to prevent the subjects from being influenced by each other.

Data Collection

After the inventory was distributed to 34 voluntary pre-service science teachers, they were informed about algorithms and flowcharts not more than 15min. They were told how they can use flowcharts while solving these 3 problems. The research was completed by pre-service science teachers in 35min although there was no time limit. After reading the data obtained from the inventory, as a security measure, the researchers tried to obtain confirmation from 3 colleagues, by having 2 physics teachers read the data. After providing the validity and reliability measures, the research was completed and in later years the work was shaped and developed and became an article.

Data Analysis

Data analysis was carried out by examining first, second, and third problem seriesly. The designed algorithmic flowcharts for each question were shown in the Figure 3, 5 and 7 respectively. First, the level of pre-service science teachers to use their algorithms related to the questions was examined. Then, the levels of being able to apply the algorithm correctly were given. This information was shown by frequency analysis. In addition, in each question, the status of pre-service science teachers' use of unit was given with frequency tables.

RESULTS AND DISSUSSION

The three problems used in the study were related to mechanics, however, the contents differed from the question. Therefore, the solution of each problem was specific to itself (Unsal, 2016). The first question is about the projectile motion, the second is about the horizontal motion, the third is about the conservation of mechanical energy.

The first step was to determine whether the correct algorithm steps are created by the pre-service science teachers in the solution processes.

The second case in the process of analyzing the data was whether the pre-service science teachers applied correctly the algorithm steps they preferred in solving the problem.

The third case in the process of analyzing the data was related to the skills of the pre-service science teachers to express the algorithm steps they used in the solution process.

The last situation regarding the data obtained in the research was related to the use of unit in problem solving processes.

The Results of Problem 1

Problem 1: A ball is thrown in such a way that its initial vertical and horizontal components of velocity are 30m/s and 15m/s, respectively. Estimate the distance the ball is from its starting point when it lands.

Solution 1: The algorithmic flowchart like Figure 3 helps to conceptualize the Problem 1. The acceleration vectors are all the same, pointing downward with a magnitude of nearly $10m/s^2$. The velocity vectors change direction. Their horizontal components are all the same: 15m/s (Serway & Beichner, 2014). Because the vertical motion is free-fall, the vertical components of the velocity vectors change, second by second, from 30m/s to roughly 20, and 10m/s in the upward direction, and then to 0m/s. Thus, it takes the ball about 3s to go up and another 3s to come back down, for a total time of flight of approximately 6s. Because the horizontal component of velocity is 15 m/s, and because the ball travels at this speed for 6s, it ends up approximately 90 m from its starting point. Algorithmic Flowchart of the Problem 1 is illustrated in Figure 3.

In terms of Problem 1 data, first, pre-service science teachers' level of using algorithms related to the problem was examined (Table 1). In this 4-step algorithm, more than 90% of pre-

Table 1. The levels of using flowchart

	Is there 1st step in the solution?		Is there 2nd step in the solution?		Is there 3rd step in the solution?		Is there 4th step in the solution	
	(f)	%	(f)	%	(f)	%	(f)	%
Yes	33	97	26	76	32	94	31	91
No	1	3	8	24	2	6	3	9

Table 2. The levels of being able to apply algorithm correctly

	To be able to apply 1st step		To be able to apply 2nd step		To be able to Apply 3rd step		To be able to apply 4th step	
	(f)	%	(f)	%	(f)	%	(f)	%
True	24	**73**	21	**81**	23	**72**	22	**71**
False	9	27	5	19	9	28	9	29
Skipped the corresponding digit	1	3	8	24	2	6	3	9

service science teachers applied 1st, 3rd and 4th steps in problem solving. While 76% of the pre-service science teachers drew diagrams about the problem they solved, 24% of them did not use the diagram.

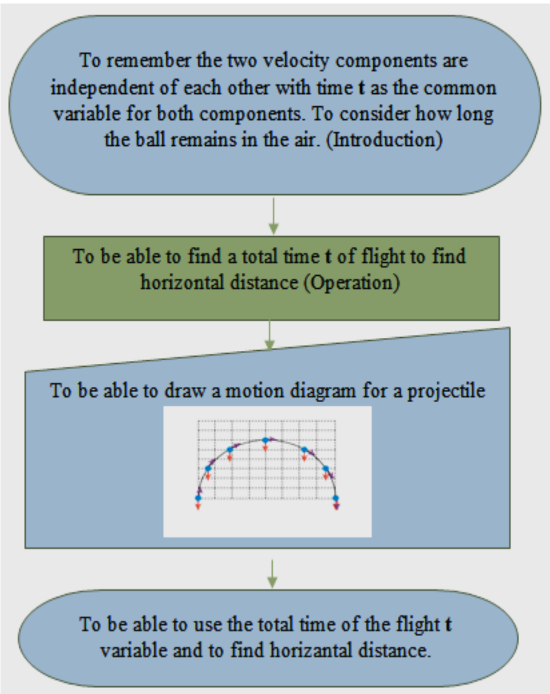

Figure 3. Algorithmic flowchart of the problem

The accuracy levels of the algorithms used by pre-service science teachers in problem solving are seen in Table 2.

It was observed that the pre-service science teachers' levels of being able to apply the algorithms used in the first, second and fourth level were around 70% and 80%. When the steps in the algorithm were examined, it was observed that they skipped the second step, which directly involved drawing the diagrams. Pre-service science teachers' levels of being able to correctly express the algorithms used in problem solving is shown in Table 3.

Table 3. The levels of being able to express algorithm they use

	f	%
Able to express algorithm	21	62
Not Able to express algorithm	13	38

According to Table 3, it was observed that more than half of the pre-service science teachers (62%) were able to express the algorithm. An example of the situation was given in Figure 4.

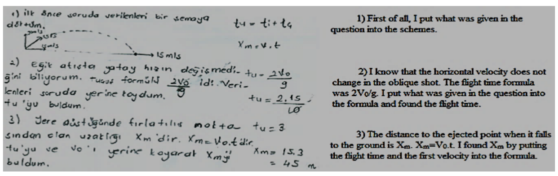

Figure 4. An example of a solution of a teacher candidate who has errors in his/her algorithm but expresses his/her algorithm well.

Another area focused in the study was the states of using unit. In the first problem, the unit using status of pre-service science teachers was less than half of the total number of pre-service science teachers (47%). This was described in Table 4.

Table 4. The level of unit usage in the operations in algorithm

	(f)	%
There is unit	16	47
There is no unit	11	32
Wrong unit	1	3
Partly used	5	15
No solution	1	3

The subjects' skills to choose the correct algorithm steps were found to be quite high in the projectile motion problem. Their performance about determining only one of the 4 digits was found slightly lower. This step was also the step that was related to the creation of the visual of the projectile motion in the problem. Some of the pre-service science teachers did not include it in the solution algorithm.

It was observed that the rates of applying the steps of algorithm chosen by subjects correctly was high in the projectile motion problem. In addition, parallel to the literature, the attitude of visualizing the problem through drawing was observed among the pre-service science teachers (Caliskan, Sezgin, & Erol, 2006).

The Results of Problem 2

Problem 2: A plane drops a package of supplies to a party of explorers, as shown in Figure 5. If the plane is traveling horizontally at 30.0 m/s and is 80 m above the ground, where does the package strike the ground relative to the point at which it is released? (The acceleration vectors are all the same, pointing downward with a magnitude of nearly 10 m/s^2).

Solution 2: Because the package is in freefall while moving in the horizontal direction, this is categorized this as a projectile motion problem. To analyze the problem, it is chosen the coordinate system shown in Figure 5, in which the origin is at the point of release of the package, is chosen. The initial x component of the package velocity is the same as that of the plane when the package is released: 30.0m/s.

Thus, we have x_f = (30.0m/s). **t.** If it is known **t,** the time at which the package strikes the ground, then it can be determined x_f, the distance the package travels in the horizontal direction (Serway & Beichner, 2014). At the instant the package hits the ground, its y coordinate is y_f = -80 m. It is also known that the initial vertical component of the package velocity v_{yi} is zero because at the moment of release, the package has only a horizontal component of velocity, (y_f= -1/2gt^2). (– 80m = -1/2(10m/s^2). t^2) and **t=4s**. Substitution of this value for the time into the equation for the x coordinate gives x_f **=** (30.0m/s).4 and $x_{f=}$ 120m. In the problem, an algorithm consisting of 4 steps was established. The algorithm solution of problem 2 was given in Figure 5.

In Table 5, pre-service science teachers' levels of being able to use the steps of the algorithm for solving the problem were examined. When the problem solutions of the pre-service science teachers were examined according to Table 5, it was seen that all the steps of the algorithms were presented in the solutions.

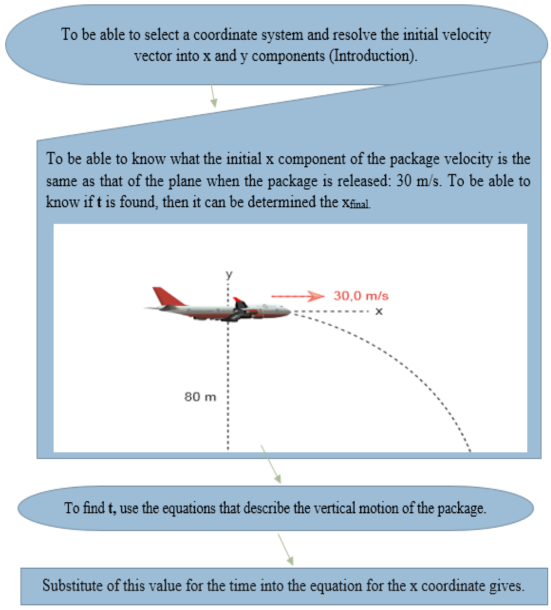

Figure 5. Algorithmic flowchart of the problem 2

The rate of presence varied. According to the findings, the most applied algorithm step in the problem was found to be the second step with 91% ratio. Pre-service science teachers' levels of using the other steps of the algorithm were in the 80-90% band. In Table 6, the pre-service science teachers' levels of being able to apply algorithms correctly were given.

According to Table 6, it was seen that the pre-service science teachers' levels of being able to apply algorithm steps correctly in problem solving varied between 57% and 93%.

While the step achieved at the lowest level was the first step, it was observed that the performance of the pre-service science teachers for the other 3 steps was around 90%. In Table 7, the levels of pre-service science te-

Table 5. The levels of being able to use the correct algorithm

	Is there 1st step in the solution?		Is there 2nd step in the solution?		Is there 3rd step in the solution?		Is there 4th step in the solution?	
	(f)	%	(f)	%	(f)	%	(f)	%
Yes	28	82	31	91	30	88	28	82
No	4	12	2	6	2	6	4	12
Blank	2	6	1	3	2	6	2	6

Table 6. The levels of being able to apply the algorithm correctly

	To be able to apply 1st Step		To be able to apply 2nd step		To be able to apply 3rd step		To be able to apply 4th step	
	(f)	%	(f)	%	(f)	%	(f)	%
True	16	57	28	90	28	93	25	89
False	12	43	3	10	2	7	3	11
Skip the corresponding digit	6	18	3	9	4	12	6	18

achers expressing their algorithms were described for Problem 2. Eighteen of them were able to express their algorithm. This rate hits more than half (53%).

Table 7. The levels of being able to express the algorithm they use

	f	%
Able to express algorithm	18	53
Not Able to express algorithm	14	41
Blank	2	6

In Figure 6, a pre-service science teachers' algorithm was given. It was observed that it automatically monitored certain processes in solving the problem.

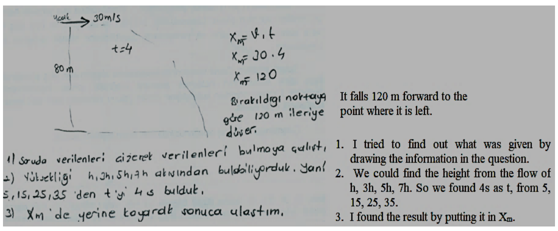

Figure 6. Drawing of a teacher candidate who has some errors in his/her algorithm but can express his/her algorithm well

When the use of unit was examined in the solution of the problem, it was seen that the use of unit by pre-service science teachers was determined as 50%. This was described in Table 8.

Finally, in the second problem, which was the horizontal projectile problem, it was seen that the rate of selecting 4 algorithm steps correctly in the problem solving was quite high.

Table 8. The Level of Using Unit in Operations in Algorithm

	(f)	%
There is unit	17	50
There is no unit	7	21
Wrong unit	2	6
Partly used	5	14
No solution	3	9

In that question, it was observed that the rate of implementation of the initial step correctly involving "origin, the point at which the package is thrown and being able to draw the coordinate plane" was low and there was no serious problem found in the other steps.

The Results of Problem 3

Problem 3: A child of mass m=20.0kg rides on an irregularly curved slide of height h =3.00m, as shown in Figure 7. The child starts from rest at the top. Determine his speed at the bottom, assuming no friction is present.

Solution 3: If the slide is frictionless, the speed of the child at the bottom depends only on the height of the slide. The child–Earth system is isolated and frictionless, however, so it can be categorized this as a conservation of energy problem and search for a solution using the energy approach (Serway & Beichner, 2014). A 3-step algorithmic flowchart was used to solve the 3rd problem. This scheme was described in Figure 7.

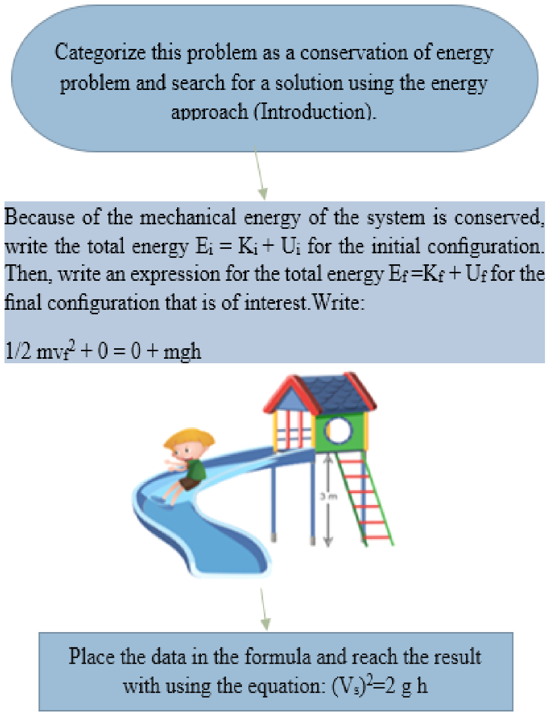

Figure 7. Algorithm Flowchart for Problem 3

Table 9 shows the pre-service science teachers' levels of being able to use algorithm steps for Problem 3.

When the data in Table 9 was examined, it was seen that the three steps in the algorithm solution of Problem 3 were used as solution steps in the solution of the subjects. The usage percentage of these steps was close to one another and around 70%.

Table 10 shows the pre-service science teachers' levels of being able to apply algorithms correctly in their solutions.

According to the data obtained from Problem 3, it was observed that the pre-service science teachers' skills to apply the correct algorithm flowchart was 100% for the 1st and 2nd steps, while it was 92% in the 3rd step.

In Table 11, pre-service science teachers' skills to express the algorithms used was examined.

Table 11. The expression levels of algorithm they use

	f	%
Able to express the algorithm	16	47
Not able to express the algorithm	11	32
Blank	7	21

According to Table 11, the ability of subjects to express their algorithm correctly with flowcharts was observed to be below 50% (47%).

In Table 12, the levels of teacher candidates using unit in algorithms were examined.

Table 12. The level of using unit in operations in algorithm

	f	%
There is unit	6	18
There is no unit	16	47
Wrong unit	4	12
Partly used	1	3
No solution	7	20

When the results about using unity is evaluated generally, it was observed that the rate of unit use was close to half in the first two questions, while the rate of unit use decreased significantly in the third question.

Table 9. The levels of being able to use the correct algorithm

	Is there 1st step in the solution?		Is there 2nd step in the solution?		Is there 3rd step in the solution?	
	(f)	%	(f)	%	(f)	%
Yes	26	76	27	79	26	76
No	1	3	7	21	1	3
Blank	7	21	-	-	7	21

Table 10. The levels of being able to apply the algorithm correctly

	To be able to apply 1st step		To be able to apply 2nd step		To be able to apply 3rd step	
	(f)	%	(f)	%	(f)	%
True	26	100	27	100	24	92
False	0	-	0	-	2	8
Skip the corresponding digit	8	24	7	21	8	24

Finally, in the third problem, which was the conservation of mechanical energy, it was found that the rates of selecting the three algorithms correctly in the solution was still high but lower than the other questions. Also, in that question, it was seen that almost all the pre-service science teachers were able to perform all the steps correctly.

In findings, the algorithm flowcharts used by the subjects in problem solving differed from one question to another, and this result paralleled some of the studies found in the Turkish literature (Eryilmaz & Akdeniz, 2019). Considering the findings obtained in the research process, it was seen that pre-service science teachers mostly used a certain algorithm in solving physics problems. One reason for it is thought to be examples of previously solved problems. However, their performance in the mentioned problem solving processes showed significant differences according to the issue to which the problem relates, the compatibility with the correct algorithms determined for the solution of the problem, the degree of accuracy if the algorithm is used, and the unit / units that should be included in the solution according to the scenario of the problem. At the same time, it was observed that some subjects applied the formulation path directly without following the algorithm steps. It is thought that this result may be in line with the idea that pre-service science teachers want to conclude automatically without thinking too much about the question (Kariper, Akarsu, Slisko, Corona, & Radovanovic, 2014). This result is thought to indicate that there may be deficiencies in the conceptual learning of the pre-service science teachers and these deficiencies may constitute a negative situation for their teaching careers. It is thought that it is of great importance to provide educational activities related to justifying the steps used especially in problem solving processes by pre-service science teachers and to gain skills in this direction for them. About the last situation which is using unity in the problem-solving process, it can be said that the use of unit is of great importance both for the correct conceptual handling of the problem and for performing the mathematical operations correctly (Yildiz, 2014). Therefore, it is found to be beneficial to carry out more detailed education on the subjects such as the meaning and the importance of unit and how it should be used in the educational processes.

CONCLUSION

When the processes of solving the problems determined in line with the scope of the research were examined, it was founded that the pre-service science teachers had not too many problems in solving the problems. However, it was observed that pre-service science teachers had problems in expressing their algorithms well, and some of them could not express these algorithms at all. It seems that the real problem here is related to explaining the processes for problem solving. Because pre-service science teachers also had difficulties in explaining their solutions. However, it was observed that pre-service science teachers who could express their algorithms well are generally the ones who solve the problems correctly. While some of the pre-service science teachers who solved the problem correctly can express their algorithms well, some of them did not, although they did solve them correctly. Here, there may be a reflection of pre-service science teachers' differences regarding situations such as field knowledge, self-regulation skills, and metacognitive awareness. For this reason, it is thought that researches involving the examination of pre-service science teachers in terms of such different situations will also be useful. In addition, it has been observed that there are important deficiencies regarding the use of units in problem solutions. This suggests that pre-service science teachers also should be supported conceptually.

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