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The Investigation of Algorithmic Thinking Skills of Fifth and Sixth Graders at a Theoretical Dimension*

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Abstract: Besides algorithmic thinking is a basic mathematical skill that places on the centre of mathematical processes such as problem solving, programming and coding, it is seen that studies related to algorithmic thinking in the literature are very limited. In this context, this study aims to investigate the algorithmic thinking skills of secondary school students at a theoretical dimension. This is a case study and the study group consists of 138 students in total studying at fifth and sixth grades of different public secondary schools in the province of Ordu. Roughly, fifty-four and forty-five percents of the study group consist of female and male and fifty and forty-nine percent of them consist of fifth and sixth graders respectively. Criteria sampling method of objective sampling methods was used in determining the study group and *Algorithmic Thinking Test* developed by the author as a data collection tool was administered to the students in the study group. As a result of the study, the algorithmic thinking skills of the students were assessed considering the sub-dimensions of these skills and students in the study group had 43% of the achievement averages in using algorithmic thinking skills at the end of the study. It is seen that *algorithmic tasks* are the most successful questions for the students, and the *logic* is the most unsuccessful. Some recommendations were presented for relevant studies that can be carried out about the subject in the future.

Keywords: algorithmic thinking, fifth and sixth graders, theoretical study.

INTRODUCTION

Informally, computational thinking describes the mental activity in formulating a problem to admit a computational solution. The solution can be carried out by a human or machine, or more generally, by a combination of humans and machines (Wing, 2006). Though the idea of computational thinking was first introduced by Seymour Papert (1980), the discussions with regard to the teaching of this concept became widespread with the notion of Wing (2006) suggesting that every student should be taught computational thinking as one of the fundamental areas such as reading, writing and arithmetic. International Society for Technology in Education [ISTE] (2015)

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indicates that computational thinking skill is an expression of creative thinking, algorithmic thinking, critical thinking, problem solving, cooperative learning and communication skills and underlines that it cannot be described independently of these skills.

Being an important component of computational thinking skill, algorithmic thinking is defined by Brown (2015) as the ability to understand, implement, assess and design algorithms to solve a range of problems. As for Futschek (2006), it is an ability that is necessary at any stage of problem solving process whereas Olsen (2000) indicates that this ability is one of the most important abilities that students should develop in educational environments. As algorithmic thinking is a component of computer thinking, it is seen that the studies on the subject are generally based on computer thinking (Grover and Pea, 2013; Korkmaz, Çakır, Özden, Oluk and Sarıoğlu, 2015; Korkmaz, Çakır and Özden, 2017; Oluk, Korkmaz and Oluk, 2018; Yünkül, Durak, Çankaya and Mısırlı, 2017) and the scope of these studies is limited. From these studies, Grover and Pea (2013), Oluk, Korkmaz and Oluk (2018) and Durak, Çankaya and Mısırlı (2017) examined the effect of scratch programme on the learners' computational and algorithmic thinking skills. Korkmaz, Çakır and Özden (2017) developed a computational thinking scale and Korkmaz, Çakır, Özden, Oluk and Sarıoğlu (2015) evaluated the students' computational thinking skills in terms of school type, department, class level / graduation status, gender and age variables by using this scale.

In particular, studies specially on algorithmic thinking skills are quite limited and these studies (Burton, 2010; Futschek, 2006; Hromkovič, Kohn, Komm and Serafini, 2016; Zsakó and Szlávi, 2012) have generally theoretical structure. From these studies, Burton (2010) examined the ways of encouraging algorithmic thinking without a computer by using a pen and-paper like multiple choice questions and three stage tasks. Futschek (2006) said in his study that algorithmic thinking is a key ability in informatics that can be developed independently from learning programming, and he put forward some problems and claimed a proper visualization of these problems can help to understand the basic concepts connected with algorithms: correctness, termination, efficiency, determinism, parallelism, etc. The study of Hromkovič, Kohn, Komm and Serafini (2016) developed three examples that illustrate how general aspects of algorithmic thinking can be incorporated into programming classes and investigated the algorithmic thinking skills of secondary school students at a theoretical dimension. Zsakó and Szlávi (2012) aimed at dealing with algorithmic thinking’s depths and made the specifications and levels of algorithmic thinking competence. Therefore, in this study, apart from the mentioned studies, the algorithmic thinking skills were handled practically and the ways in which the students used this skill were investigated. The aim of the study is to investigate the algorithmic thinking skills of secondary school students at a theoretical dimension.

METHOD

The survey method was used in this study. Survey studies aims to collect data for determining specific characteristics of a group (Büyüköztürk, Kılıç-Çakmak, Akgün, Karadeniz and Demirel, 2018). In this study, it is preferred to use this method since it has been studied by taking a special mathematical competence, together with its sub-dimensions.

Study Group

The study group consists of a total of 138 students in fifth and sixth grade levels in different state secondary schools in Ordu. Criteria sampling method of objective sampling methods was used for determining the study group (Patton, 1990). For determining the schools that would take part in the study, the TEOG (Transition from Primary to Secondary Education) exam results carried out in 2017 were taken into account, in line with the consensus of mathematics teachers and school principals across the province. In this regard, the students studying at schools that ranked in the middle group according to success rating participated in the study. The students who have been attending fifth and sixth grades and also volunteer for the study were selected. The demographic information of these students is as follows.

Table 1: The distribution of study group according to the independent variables

	Gender		**Grade Level**	
	Girl	Boy	5	6
N	75	63	70	68
%	54.34	45.65	50.72	49.27

Data Collection Tools

Algorithmic Thinking Test (ATT) developed by the researchers and consisting of 12 open-ended questions was used as data collection tool in the study. The theoretical structure of Burton (2010) was used for developing the questions in the test. Accordingly, the test consists of four sub-dimensions: *Algorithmic Tasks, Tracing Tasks, Logic Tasks* and *Analysis Tasks.* Besides, online data sources (Kalelioğlu, 2017) were utilized in the determination of the questions in ATT. Information on the scope of the questions in each sub-dimension of ATT is given below.

Algorithmic tasks

In these questions, the students use a given algorithm according to the rule of a problem or develop an algorithm to solve a given problem.

Tracing tasks

In these questions, the students use the steps of a given algorithm in accordance with the current situation / problem situation or predict the result of an algorithm given in the problem.

Logic Tasks

In these questions, the students use the reasoning skills effectively for determining and using the appropriate algorithms for the problem situations.

Analysis tasks

In these questions, students are asked about the correctness / effectiveness of the algorithms used in the given problems. Students can also determine the inappropriate step of an algorithm or determine the sequence of the steps of an algorithm that best suits for the expected solution.

The ATT consists of eight questions in total, having 3, 2, 2 and 1 questions for each dimension respectively. For the validity of ATT, the difficulty and discriminatory indices of the items were examined and the expert opinions were used for the reliability of the test. As a result of the examination, four problems were removed from the test because of the discrimination values were below 0.20. The average strength of the test was calculated as 0.44. Accordingly, it can be said that the difficulties of the questions in the test are moderate. Finally, the Spearman Brow coefficient for internal consistency was calculated as 0.75 for the test.

Data Analysis

The responses of students in the study were interpreted by expressing the percentage and frequency values for each sub-dimension of the ATT.

FINDINGS

General Findings Obtained from ATT

Findings obtained from ATT are given in Table 2.

Table 2: Findings Obtained from ATT

Dimensions of ATT	Number of	N	x	ss
Algorithmic	3	138	**0.53**	.31
Tracing	2		**0.46**	.77
Logic	2		**0.32**	.34
Analysis	1		**0.34**	.47
Total	8		**0.43**	.24

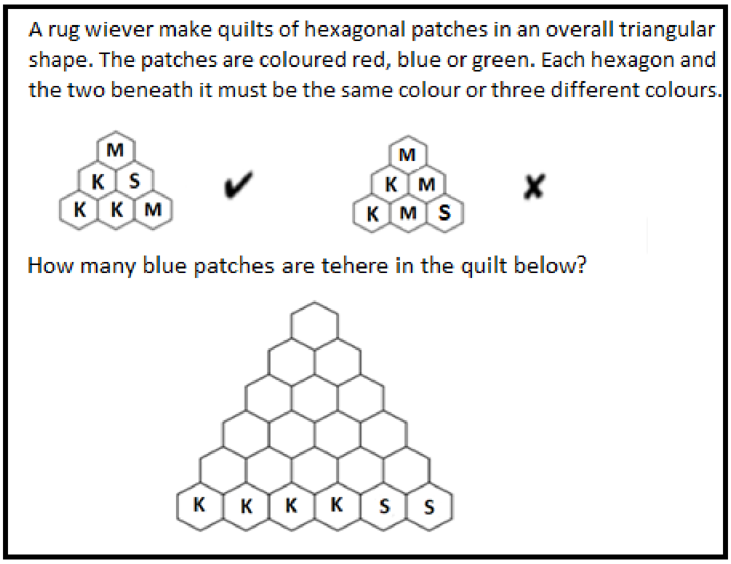
According to Table 2, it can be said that the students in the study group had 43% of the achievement averages for using algorithmic thinking skills. This value for each sub-dimensions of ATT were calculated as 0.53, 0.46, 0.32 and 0.34 for algorithmic, tracing, logic and analyses tasks respectively. According to these values, it is seen that the most successful dimension for the students is *algorithmic tasks* and the most unsuccessful is *logic tasks* of ATT. So, it can be said that the students are more successful in using given algorithms according to the rule of a problem or developing an algorithm to solve a given problem while they have difficulties for using reasoning skills effectively for determining and using the appropriate algorithms for the problem situations.

Findings Obtained from Sub-Dimensions of ATT

In this section, examples of the questions in the sub-factors of ATT and the achievement averages of the students in the relevant questions are given.

Algorithmic tasks

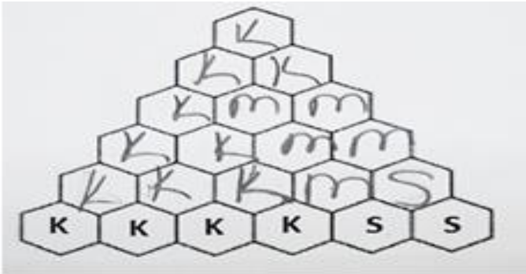
Figure 1: Sample question placed in *Algorithmic Tasks* of ATT.



It is necessary to use the rules (steps) of the given algorithm in this problem. For this reason, it placed in the dimension of *algorithmic tasks*. 53.62% of the students answered this question correctly. The right and wrong student solutions for this question are exemplified below.

Figure 2: The true answer of S_{28}.

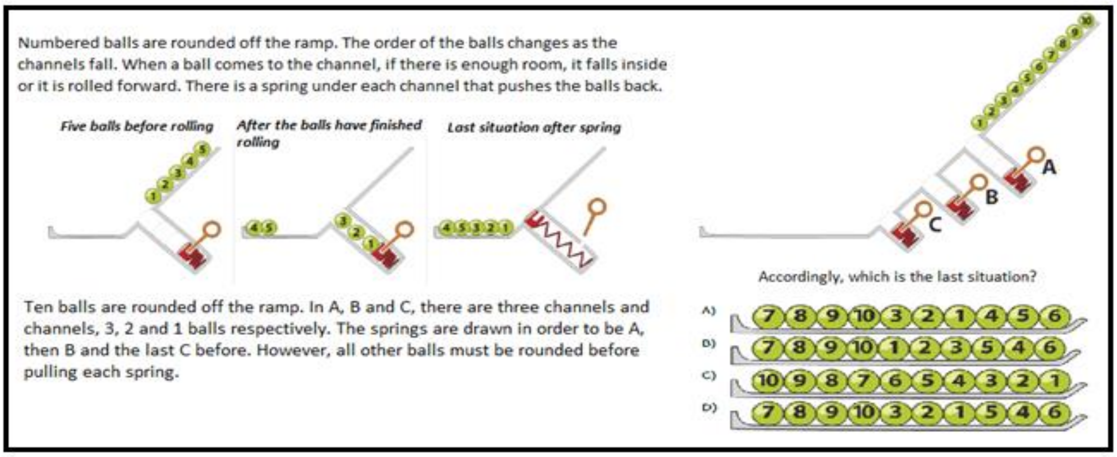
Figure 3: The wrong answer of S_{42}.



In Figure 2, it is seen that the student can determine the steps according to the given rule of algorithm. In Figure 3, the student had difficulty to create the appropriate steps for the given algorithm.

Tracing tasks

Figure 4: Sample question placed in *Tracing Tasks* of ATT.



It is necessary to guess the result of the algorithm given in this question. For this reason, it placed in the dimension of tracing tasks. 32.60% of the students answered this question correctly. The right and wrong student solutions for this question are exemplified below.

Figure 5: The true answer of S_{37}.

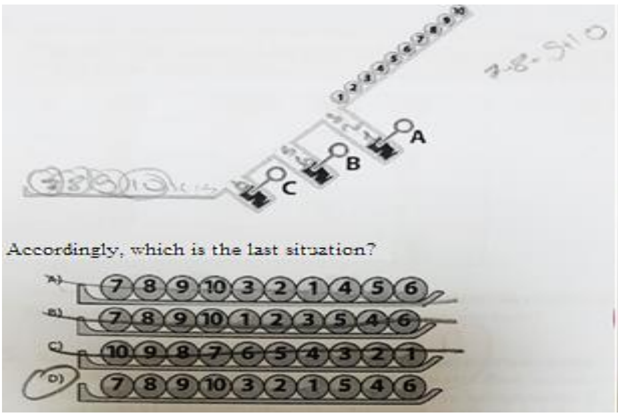
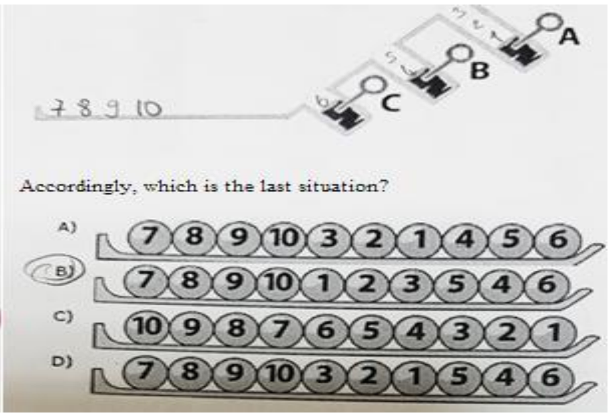


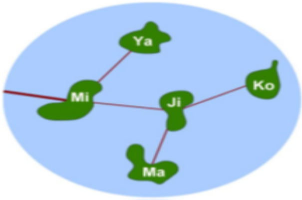
Figure 6. The wrong answer of S_{18}.



It can be seen that the student in Figure 5 gives correct answers about the order in which the balls are arranged. The student in Figure 6 has made incorrect determinations about the order in which the balls falling into the channels will be arranged after the springs are pulled.

Logic tasks

Figure 7: Sample question placed in *Logic Tasks* of ATT.



The Miyakojima archipelago includes 5 islands, Mi, Ya, Ko, Ji and Ma. Mi is the largest archipelago. It is connected to the Internet with a large cable. Also, Mi and Ya, Mi and Ji, Ji and Ko, and Ji and Ma are connected by small cables. With these cables, all islands are connected to Mi' and therefore to the Internet.People living in Miyakojima want all the islands to remain connected to the Internet, even if there is a problem with any small cable. Therefore, the Internet needs to be flexible and durable.

If only two cables are to be connected to the Internet network to be flexible and durable, which of these two cables is correct?

A) It must be connected between the Min and Ma, Ya and Ko.
B) It must be connected between Ji and Ma, Ko and Ma.
C) It must be connected between Ji and Ya, Ya and Ko.
D) Two additional cables are not sufficient to make the Internet network flexible and durable.

It is necessary to use the given algorithm for the desired solution of the problem with the effective use of reasoning skill. 44.92% of the students answered this question correctly. Besides 26.81% of the students marked D option and 14.49% of the students marked B option of this question. 13.76 of the students did not answer this question. When these answers are examined, it can be said that the students think that there should be a cable between the islands in order to share the internet mostly, and they ignore the algorithmic logic given in the question.

Analysis tasks

Figure 8: Sample question placed in *Analysis Tasks* of ATT.

A school of espionage training teach students the way to hide messages (encryption). Accordingly, the original message must replace each letter according to one of the following rules.

- XY instead of V
- Z instead of W
- WV instead of X
- V instead of Y
- VW instead of Z

Spies are not used in messages except W, V, X, Y, Z. The trainer gives a message to Ali. Ali encrypts the message according to the above rules and sends it to Ahmet. Ahmet re-encrypts the message and sends it to Ayşe. Ayse encrypts the message and sends it to the trainer. If the message received by the trainer is in VZZXYXY format, the first message the trainer sends is the following.

A) V B) W C) X D) Y E) Z

It is necessary to determine the sequence of steps that best suits the expected solution for this problem. 34.05% of the students answered this question correctly. The right and wrong student solutions for this question are exemplified below.

Figure 9: The true answer of S_{43}.

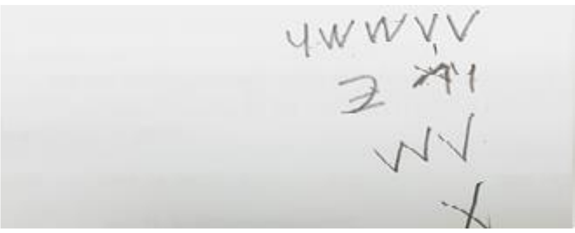
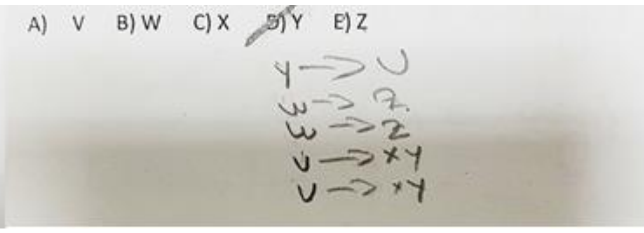


Figure 10: The wrong answer of S_{47}



In Figure 11, the student appears to solve the problem correctly by making reverse coding. Figure 12 shows that the student could not understand the logic of the algorithm given in the question and solved the question incorrectly.

DISCUSSION AND CONCLUSION

In this study, the algorithmic thinking skills of fifth and sixth grade students were examined and the results show that students cannot use these skills effectively. It has been observed that students are more successful in using a given algorithm and monitoring their progress than developing, using, or determining the effectiveness of an algorithm that is appropriate for the current situation. It is thought that there is a need for enriching the learning environments with the activities to ensure that students develop their algorithmic thinking skills. With the development of this skill, it is thought that students will develop computational thinking and programming skills in this context. Because algorithmic thinking is one of the sub-dimensions of computational thinking and programming (Gökoğlu, 2017; ISTE, 2015).

When the literature is examined; it is stated that the students who have programming education have different thinking, creativity, metacognition and orientation skills than the students who don't have (Clements and Gullo, 1984). Besides programming education has been found to be effective in teaching mathematical subjects, developing problem solving strategies, collaborative, systematic and creative thinking that many studies (Ananiadou and Claro, 2009; Department of Education Research and Development [EARGED], 2011, Pinto and Escudeiro, 2014; Trilling and Fadel, 2009) suggest for individuals to have in the 21st century. Research on programming education and algorithm concept examine the reasons for the failures of students in their programming lessons and the difficulties they experienced during the process (Özmen and Altun, 2014), and generally several approaches (Arabacıoğlu, Bülbül and Filiz, 2007; Durak, 2009; Ersoy, Madran and Gülbahar, 2011; Köse and Tüfekçi, 2015) have been developed to be used in teaching programming and algorithmic logic (cited from Gökoğlu, 2017). In the study of Özmen ve Altun (2014) examining the difficulties experienced during the programming process, the students emphasized that the biggest causes of their failure in programming are lack of information, inadequacy of implementation and lack of developing an algorithm. So, it can be said that these results are in line with the results obtained from the present study.

Besides, algorithms include not only the scheduling of the programming but also all the finite-processes that people are doing in their daily lives (Akçay and Çoklar, 2016). Therefore, this skill is also needed for people to use and find solutions for their problems in daily lives. So, there must be new and different scientific studies to improve the algorithmic thinking skill which is one of the most important skills required by the human profile of the future. In these studies, it is suggested to develop written materials based on problem solving and reasoning processes different from the existing studies. It is thought that mathematical reasoning and problem solving skills are also thought to be influential for the development of algorithmic thinking skills in addition to technological tools and software.

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