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The Investigation of Algorithmic Thinking Skills of 5th and 6th Graders According to Different Variables *

Hayal Yavuz Mumcu[1], Suheda Yıldız[2]

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Abstract: Besides algorithmic thinking is a basic mathematical skill that places on the center of processes which has great importance today, 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 according to different variables. This is a case study and the study group consists of 138 students in total studying at 5th and 6th grades of different public middle schools in the Ordu, Turkey. Roughly, fifty-four and forty-five percent of the study group consist of female and male students, fifty and forty-nine percent of them are 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 authors was administered to the students in the study group. The study found out a positive but low correlation between students' algorithmic thinking skills and mathematics achievements. There were also significant differences between algorithmic thinking skills of the students by gender and grade level. The differences were in favor of females and 6th grade students, respectively. At the end of the study, some recommendations were presented according to the obtained results and for relevant studies that can be carried out about the subject in the future.

Keywords: algorithmic thinking skill, gender, grade level, middle school student.

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 combinations of humans and machines (Wing, 2006). Although the idea of teaching computational thinking was first brought forward by Seymour Papert (1980), debates on teaching

[1] **Corresponding Author:** Hayal Yavuz Mumcu, **e-mail**: hayalym52@gmail.com, Asst. Prof., Ordu University
[2] Suheda Yıldız, **e-mail**: suhedayildiz.b@gmail.com

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this concept became widespread following Wing's (2006) view that computational thinking should be taught to every student as a fundamental area, just like reading, writing, and arithmetic. ISTE (2015) 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 education environments. Nevertheless, the studies carried out on algorithmic thinking are fairly limited, Thus, the present study aims to investigate the algorithmic thinking skills of middle school students according to the gender, grade level and mathematics achievement variables. Research questions of the study are as follows.

- How are the students' algorithmic thinking skills generally?
- Is there any significant mean difference between male and female students' algorithmic thinking skills?
- Is there any significant mean difference between 5^{th} and 6^{th} graders' algorithmic thinking skills?
- Is there meaningful relationship between the students' algorithmic thinking skills and mathematics achievements?

METHOD

In this study, relational survey model was used. Survey studies aim to describe specific characteristics of a group (Büyüköztürk, Çakmak, Akgün, Karadeniz, & Demirel, 2009) or determine the degree of change and / or degree between two or more variables (Karasar, 2005). This method was suitable for this study, since the variables of gender, grade level and mathematics achievement affecting a specific mathematical skill as algorithmic thinking were investigated and reported.

Sample

The sample consists of a total of 138 students in 5^{th} and 6^{th} grade levels of different state middle 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. From these students who have been attending 5th and 6th grades and also volunteer for the study were selected. The demographic information of these students is as follows.

Table 1: Demographic characteristics of the students in the study group

	Gender		Grade Level		Mathematics Achievement	
	Girls	Boys	5	6	<50	>=50
N	75	63	70	68	22	116
%	54.34	45.65	50.72	49.27	15.94	84.05

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 were utilized in the determination of the questions in ATT.

Process

This study consists of two parts; pilot and main study. The pilot study was conducted with 59 students attending fifth (28 students) and sixth (31) grade levels in total who are in one of the schools determined according to the criteria of the study. In this process, it was observed that some students had difficulty in understanding some of the questions in the ATT, so these questions were rewritten taking into account the results of the observations. According to the results of the pilot study, ATT item difficulty and discriminatory indices were calculated and then 4 problems were removed from the test because of the discrimination values were below 0.20. The last version of the ATT consists of 8 questions in total, having 3, 2, 2 and 1 questions for each dimension respectively. 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. The indices of discrimination and difficulty of the items in ATT calculated at the end of the pilot study are presented in Table 2.

Table 2: Item indices belong to ATT

ATT Items	Discrimination indices	Difficulty indices
I1	.54	.53
I2	.52	.61
I3	.56	.59
I4	.34	.49
I5	.49	.45
I6	.51	.54
I7	.54	.62
I8	.43	.64

Apart from the pilot study, the opinions of two lecturers who were experts in the field of *mathematics education* and *computer & instructional technology education* were used for the validity of ATT.

The main study was conducted with 138 students in sample group. When administering ATT, permission has been obtained from course teachers and school principals. One of the researchers of this study carried out all the application processes (pilot and main study) in schools and made all student and environment controls by himself. In the implementation of the questions, the students were given one course-hour for 8 open ended questions in total and no additional time has been given to the students. Finally, the Spearman Brown coefficient for internal consistency was calculated as 0.75 for the reliability of the test.

Analysis

In the evaluation of the students' data obtained from ATT, the correct answers were coded as 1, and the incorrect ones as 0, an ATT score was obtained for each student. These scores were interpreted by expressing percentage and frequency values for ATT. Besides independent groups t-

test was used for determining the differences between sub-groups according to the gender and grade levels. Pearson correlation analysis techniqu was used for determining the relationship between algorithmic thinking skills and mathematics achievements of students. The first semester school scores for fifth grade students, and the three-semester scores for sixth grade students were used for determining the students' mathematics achievements with the help of school administrators.

FINDINGS

General Findings Obtained from ATT

Findings obtained from ATT are given in Table 3.

Table 3: Findings Obtained from ATT

	Number of Questions	N	$\bar{X}$	ss
Total	8	138	**0.43**	.24

According to Table 3, it can be said that the students in the study group had 43% of the achievement averages for using algorithmic thinking skills. So, it can be said that the students use subject skills below average level.

General Findings Obtained from ATT According to Gender and Grade Level Variables

Independent samples t-test for determining the differences between the groups according to gender and grade level variables are given in Table 4.

Table 4: Findings According to Gender and Grade Level

		N	$\bar{X}$	ss	sd	t	*p*
Gender	Girls	75	4.06	2.02	135.308	3.99	.000**
	Boys	63	2.84	1.57			
Grade Level	5^{th}	70	2.51	1.40	124.342	-7.161	.000**
	6^{th}	68	4.52	1.86			

*P**<.01*

According to Table 4, it's seen that there are significant differences between boys and girls ($t_{135.308}$ = 3.99, p<.05) in favor of girls, and there are significant differences between fifth and sixth grade students ($t_{124.342}$ = -7.161, p<.05) in favor of sixth grade students.

General Findings Obtained from ATT According to Mathematics Achievement Variable

The results of the correlation analysis carried out for the analysis of the relationship between mathematics achievement and algorithmic thinking skills are given in Table 5.

Table 5: The Correlation Analysis Results Between Mathematics Achievement and Algorithmic Thinking Skill Variables

		Algorithmic Thinking	Mathematics Achievement
Algorithmic Thinking	Pearson Correlation	1	.298
	Sig. (2-tailed)		.000
	N	138	138
Mathematics Achievement	Pearson Correlation	.298	1
	Sig. (2-tailed)	.000	
	N	138	138

**Correlation is significant at the 0.01 level (2-tailed).

According to Table 5, there is a positive but low level of correlation between students' algorithmic thinking skills and mathematics achievements. So, it can be said that as the mathematical achievements of the students increases, the algorithmic thinking skills increase too.

DISCUSSION, CONCLUSION AND SUGGESTIONS

In this study, the algorithmic thinking skills of 5th and 6th grade students were examined and the results show that students are not able to use these skills effectively. Besides, it has been observed that students are more successful in using a given algorithm and monitoring it, compared to developing, using, or determining the effectiveness of an algorithm that is appropriate for given situation. These results are similar to some research (Gülbahar, Kalelioğlu & Doğan 2015; Korkmaz, Çakır, Özden, Oluk & Sarıoğlu, 2015) results in the literature. Bilge Kunduz activity (Bebras International Challenge on Informatics and Computational Thinking), which has been organized in different countries since 2004, was organized as a pilot in 2014 for the first time in Turkey. The sample of this comprehensive research was 13.784 students that were attending 5th and 6th grade levels of their schools and the results show that most of the students in this research could make just easy level questions in the activity and only 33% of the students could make advanced questions. Furthermore, the study of Korkmaz et al. (2015) investigates the computational thinking perceptions of secondary students, and it was seen that Algorithmic Thinking is one of the sub-factors of computational thinking which the students had the lowest average. So, the results of the current study can be said to be parallel with these studies' results and according to this observation, it can be said that the students in our country are not very successful in the computational and algorithmic thinking processes generally. According to these results, it is thought that algorithmic thinking skills of students need to be improved in our country. 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 (ISTE, 2015; Gökoğlu, 2017). Also Kalelioğlu, Gülbahar & Kukul (2016, p.593) study which define computational thinking as a problem solving process and put *algorithmic thinking* as the third step of this process as *generate, select and plan solutions* of subject problems can be shown to support this discussion. So, it can be said for a student whose algorithmic thinking skill is poor/high will probably poor/high computational thinking skill too.

One of the other results obtained from this study is that female students use algorithmic thinking skills more effectively than male students. When we look at the studies conducted in the literature, there are studies which have different results including gender variable. Although there

are studies (Oluk, 2017, Atmatzidou & Demetriadis, 2016, Orton, Weintrop, Beheshti, Horn, Jona, & Wilensky, 2016; Gülbahar, Kalelioğlu & Doğan, 2015) having similar results with this study, there are also studies (Korkmaz et al., 2015; Bilge Kunduz, 2016, as cited in Oluk, 2017) that have results in the opposite direction. According to the report of Bilge Kunduz study (2016), it is seen that male students' scores are higher than female students (cited in Oluk, 2017) while Korkmaz and others (2015) point out that the students' computational thinking skills are not differentiated by gender. So, different results of related studies can be interpreted that gender is not a determinant for algorithmic thinking ability for all the situations. Nevertheless, the results obtained from this study can be explained by the students' characteristics in the sample group, as Atmatzidou and Demetriadis (2016) points out that there were certain differences identified for students' computational thinking skills related to factors as student' cognitive developmental levels and their ages. So, the results of this study according to gender variable, can be interpreted with related to these factors. Besides, it can be said that there is a need to conduct different related studies with larger samples for getting more reliable data on the subject. The data obtained from these studies will be more effective in interpreting the gender variable in relation to the algorithmic thinking skill of the students.

According to the grade level variable, this study shows that sixth grade students have meaningfully higher scores for using algorithmic thinking skills than fifth graders. The studies conducted on different age groups (Korkmaz et all., 2015; Oluk, 2017; Atmatzidou & Demetriadis, 2016) in the literature generally report that computational/algorithmic thinking levels decrease as the grade level increases. Korkmaz et al. (2015) examined university students' algorithmic thinking skills and they found that senior students had the lowest scores for subject skill. Oluk (2007) examined algorithmic thinking skills of middle school and high school students in his study and he found that the students had the highest level of skill in 4th grade. Skill levels were reported as fourth, sixth, eighth and tenth grades from high to low respectively. The lowest level was found at twelfth grade students between the sample group. Atmatzidou & Demetriadis (2016) has examined the students' algorithmic thinking skills in the age range of 15-18, and they found that students in the young age group have achieved a higher average than the older age group of students. So it's seen that for university, high school and middle school graders, related studies have all similar results as subject skill decreases as grade level increases. But at this point, it's important to look at the study results which have similar samples with this study. When the study of Gülbahar, Kalelioğlu & Doğan (2015) is examined which is a comprehensive study and has similar age group students, it is seen that the results were similar and sixth graders use subject skills more effectively than fifth graders. Likewise, different studies in the literature emphasizing specific age groups for the subject skill. Touretzky, Marghitu, Ludi, & Bernstein (2013) points out for children aged 10–17 to have especially on deep and abstract understanding of programming concepts and Grover (2011) report positive results on the development of computational thinking skills regarding elder children (Junior and High School students). So, it can be said that age group is a significant factor for computational/algorithmic thinking skills to be gained by students and it's more easy for elder children have subject skills than older ones. Besides, when the sixth grade is considered it's taught for this level to be a critical age for students to have computational/algorithmic thinking skills. So, with these considerations, it's suggested for related studies to be planned according to this age level for the students. Also, this study is limited with only fifth and sixth graders, related studies can be conducted on seventh and eighth grade students to see grade level differences for middle school term more clearly.

Another result of this study is there was a positive but low level of correlation between students' algorithmic thinking skills and mathematics achievements. This result is parallel with (Barcelos & Silveira, 2012; Oluk, 2017; Liu & Wang, 2010; Weintrop, Beheshti, Horn, Orton, Jona, Trouille, & Wilensky, 2016) conducted on this subject. Except these studies Wing (2008) suggests that computational thinking generally sharing the same routes with mathematical thinking for problem solving processes. Wing (2010) argues that computational thinking problems have a structure that overlaps with logical thinking and problem solving processes include mathematical/logical thinking. Besides Calao, Leon, Correa, & Robles (2015) found in their study that, mathematics course has contributed to the development of the students' understanding of the mathematical processes through the curriculum study which was added to improve computational thinking skills. So, it can be said that with improving students' computational and algorithmic thinking skills, we also improve their mathematical thinking skills like problem solving, reasoning, making connections between different situations and finding the best solutions for problems.

Futschek (2006) defines algorithmic thinking as a special problem-solving skill that involves different abilities and Futschek & Moschitz (2010) defines the essence of this skill as abstract and logical thinking, creativity and problem-solving skills. Hubalovsky, Milkova, and Prazak (2010) said that developing algorithmic thinking skills also improves logical thinking skills in individuals. So, it can be said that one of the most important earnings that can be achieved for students is algorithmic thinking skill for not only in the field of information technology but also in all other fields (Oluk, 2017). One of the targeted qualifications for developing countries in primary and secondary education is algorithmic thinking (Zsakó & Szlávi, 2012), and the development of algorithmic thinking is crucial for students (Ioannou & Angeli, 2016). So, it is suggested for teachers to plan and carry out special activities that improve algorithmic thinking skills of students. These activities should be implemented especially on early ages and mainly for sixth grade students. Because of the fact that it's easier to develop subject skill in early ages, and this skill has strong relationships with mathematical skills, it is suggested that *Mathematics* and *Information Technologies and Software* courses are designed and carried out in relation to each other for especially early ages of students. So, the curriculums of these courses may include activities that support each other. Besides it is suggested for the teachers of these courses should be in constant communication and cooperation with each other in schools.

Besides there are studies on computational thinking in the literature, it is seen that the studies carried out on algorithmic thinking are very limited and most of the existing studies including algorithmic thinking skill examine this skill in the context of computational thinking skill. So there is a need to plan and carry out studies which include algorithmic thinking skill independent from other concepts or skills. This study is limited with 138 students from fifth and sixth graders and ATT developed by the researchers. So, the studies that will be carried out are suggested to have a larger and different age group of students and contain different data collection tools which have different cognitive components and theoretical frameworks. With suggested researches and implementations in schools, it's taught that algorithmic thinking and its related factors can be understood by researchers and students more deeply and this situation contributes to the development of subject skills of all age group of students.

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