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The Effects of Subject-Based Critical Thinking Education in Mathematics on Students' Critical Thinking Skills and Virtues*

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ABSTRACT

Purpose: "Good thinking" has become very important in today's world. A good thinker should have critical thinking skills as well as critical thinking virtues. Some researchers stated that teaching critical thinking within certain disciplines and subject areas would significantly contribute to the development of students as strong critical thinkers. Mathematics is one of the ways to improve thinking and it has many things in common with critical thinking. In this context, the aim of this study is to examine the effects of subject-based critical thinking education in math on student's critical thinking skills and critical thinking virtues.

Research Methods: In this study, a quasi-experimental model with pre-test-post-test control groups was applied. 62 sixth grade students were involved in the study. In the experimental group (n=31), the subject-based critical thinking education was given for 16 weeks. Mathematical Critical Thinking Test (MCTT) and Critical Thinking Virtues Perception Scale (CTVPS) were applied as pre-test and post-test in the groups.

Findings: As a result of the covariance analyses, it was determined that there was a statistically significant difference in terms of the MCTT and CTVPS post-test scores in favour of the experimental group. As a result, it was observed that education in the experimental group had a positive effect on students' critical thinking skills and critical thinking virtues.

Implications for Research and Practice: This study provides an exemplary implementation regarding improving critical thinking skills and critical thinking virtues of the students. It can be said that subject-based critical thinking teaching at different grade levels and in different courses will contribute to the education of good-thinking individuals.

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Introduction

In 21st century, as science and technology rapidly advance, individuals that are capable of successfully thinking, identifying the problems, and creating effective solutions for these problems are needed. From this aspect, critical thinking has become a topic, which must be given importance to in the field of education (Facione, 1990; Miller, 2003). Nowadays, schools are expected to educate individuals, who are capable of learning to access knowledge, solving problems, and tolerantly approaching different ideas, as well as having critical thinking skills (Aybek, 2006). This objective can be achieved only by organising the curriculum in a way that meets the requirements.

Critical thinking dates back to the dialogues of Socrates 2500 years ago and, through the changes and advances by the contributions of different philosophers in the course of time, it has reached the present day (Koc, 2007). There are different approaches to critical thinking, as there are many definitions of it. Different individuals have given different answers to the question "what is critical thinking" (Bowman, 1987). According to Norris (1985), critical thinking refers to students putting their previous knowledge into practice and to changing their preliminary knowledge by giving valuing their own thoughts. Paul (1995) defines critical thinking as a disciplined and self-directed learning process exemplifying the perfections of thinking in accordance with a specific type or field of critical thinking. "Critical thinking", which gained gradually increasing importance in our education system together with the constructivist approach, contributes to the education of constructive, creative, productive individuals who have character, the power of independent and scientific thinking, and a broad world view.

Some of the studies carried out in our country showed that the levels of students' critical thinking are at insufficient levels (Akar, 2007; Akilli, 2012; Ersoy & Baser, 2011; Kayagil, 2010). The development of critical thinking is not always in the desired direction for various reasons, Akinoglu (2001) lists some of these reasons as follows: crowdedness of classes, education of teachers in an environment lacking critical thinking, teachers preferring traditional teaching methods, teachers' inability of time planning, isolation of the teacher, teachers not expecting the students to ask questions, lesson books lacking to support critical thinking, the presence of very superficial and large lesson contents, defining education as the transfer of knowledge, not establishing an interactive discussion environment, and students using memorising techniques to get good marks without allocating time for creative and critical thinking. Paul and Elder (1997) empathised two aspects of thinking for students to be able to think at better levels: defining the parts of thinking and evaluating thinking. These parts are the components of rational thinking and they are evaluated by using standards of rational thinking. Moreover, Nosich (2011) stated that there are two requirements of critical thinking. First, thinking should be reflective and in this case, the components of reasoning must be used. Nosich (2011) specified 8+ components of critical thinking (purpose, question at issue, assumptions, implications and consequences, information, concepts, conclusions and interpretations, point of view, context, and alternatives). These components are in continuous interaction with each other and this interaction is

defined as follows: critical thinking refers to analysing a question, a discipline and/or a subject in terms of these components and understanding the logic of how they adapt to each other. By thinking about what we do, we can see that we do all of them for a purpose. When we think of anything in depth, we try to identify the problem and we always need to start from something (assumptions). Our thinking, which starts from anywhere, always ends at anywhere. At the point that it ends, the implications and consequences of our logic show up. In order to think long and hard, the concepts related with the information and the concepts are needed. At the end of our thinking, we achieve and interpret the results. We think within a specific point of view. When we think deeply, we realise that there are always alternatives. We always deeply think within a context.

Second, this reflective thinking should meet high standards. These standards are clearness, accuracy, importance-relevance, sufficiency, depth, breadth, and precision. According to Nosich (2011), if your thought is understood easily and it is not liable to be misunderstood, then it is clear. The thoughts and words are true only if they are in accordance with what they are in reality. In the standard of importance-relevance, it is required to focus on an important point and that thinking must be relevant, central, and important to that point. If the subject is thought about reasonably enough and all of the necessary factors are taken into account, then it is sufficient. It is deep if the underlying theories, explanations, and complexities are appropriately taken into consideration. If the subject is considered with all of its aspects, all of the other perspectives, and all of the other relevant subjects, then it is broad. If the sufficient details related to the subject are provided and if the specific aspects are discussed, then it is precise. Besides that, to be a critical thinker, it is a requirement to be a virtuous thinker (Hamby, 2013). Critical thinking virtues (words and the intellectual virtues) constitute a characteristic of the character and mind that is needed for the right action and thought. Among critical thinking virtues, the intellectual humility refers to obtaining information about the illiteracy; intellectual courage refers to being disposed to challenge the beliefs; intellectual empathy refers to realising the need to metaphorically putting oneself into some other's shoes to really understand them; intellectual integrity refers to remaining faithful to one's own thinking and consistently complying with intellectual standards (to which others are expected to obey); intellectual perseverance refers to keep working on an intellectual task despite of all of the obstacles and complexities; confidence in reasoning refers to the belief that the one can do their best when there is a suitable environment; intellectual autonomy refers to being an independent thinker which means having internal motivation based ideally on thinking by oneself; and fair-mindedness is defined as the will and awareness of the need for behaving equally to all thoughts regardless of the interest of one's own or that of others, and these virtues are within a rotational cycle (Paul, 1995). Baehr (2013) emphasised that, in today's world of education adopting the "lifelong learning" concept as a principle, it is necessary for individuals to have various intellectual virtues in order to be a lifelong learner.

When reviewing the literature, it is seen that there are few studies on the components and standards of critical thinking (Aybek, Cetin & Basarir, 2014; Arisoy,

2015; Aybek, Aslan, Dincer & Arısoy, 2015), but there is no study on how the individuals can apply the components and standards of critical thinking to their thoughts. Given the literature on critical thinking virtues, it can be seen that no study was carried out on critical thinking virtues in Turkey, except for developing the Intellectual Courage Disposition Scale (Saracaloglu, Yoldas, Kesercioglu & Tari, 2009). On the other hand, it was also determined that studies on critical thinking virtues were recently carried out abroad and they were reported that a successful critical thinker should also possess critical thinking virtues (Hamby, 2013; 2104). However, no study on how the individuals will practically gain critical thinking virtues could be found.

Critical Thinking and Mathematics

Scriven and Paul (2005) emphasised that human beings are not born with the capacity of critical thinking and they cannot naturally develop critical thinking either, but critical thinking is a skill that is learned later on. As other skills, critical thinking skills can also be taught, learned, and developed via practice and use in daily life (Jackson, 2000). One of the fields, in which critical thinking skills can be effectively used, is mathematics.

In literature, there are studies reporting that there is a directly proportional relationship between critical thinking and academic success in maths class (Akbiyik, 2002; Brown, 2016; Guay & McDaniel, 1977; Gunhan, 2006; Kayagil, 2010; Obay, 2009). Paul, Binker, Jensen and Kreklau (1990) stated that teaching the components and standards of critical thinking, the characteristics of mind, and critical thinking skills within specific disciplines and topics would significantly contribute to the development of students as strong critical thinkers (cited by Sahinel, 2001). It was determined that, although the subject-based critical thinking education is included in the curriculum in our country (MEB, 2014), it is not successfully implemented in maths lessons and there are few studies on this subject (Obay, 2009; Sezer, 2008). Besides that, it was also determined that the studies generally focused on the skill dimension of critical thinking and the dimension of virtues was generally neglected. When all of these are taken into consideration, it is thought that maths activities planned in parallel with critical thinking skills and critical thinking virtues would positively contribute to the development of the students' critical thinking skills and critical thinking virtues. In this regard, this study aims to address the following questions:

A 6th-grade math lesson was applied between the experimental group, in which the subject-based critical thinking education was given, and the control group, in which the current curriculum;

1. Is there a significant difference between the post-test scores when the Mathematical Critical Thinking Test (MCTT) pre-test scores are controlled?

2. Is there a significant difference between the post-test scores when the Critical Thinking Virtues Perception Scale (CTVPS) pre-test scores are controlled?

This study is expected to contribute towards students in successfully performing thinking within the context of critical thinking standards and components, as well as adapting intellectual virtues to their thoughts. Besides that, among the studies carried

out on critical thinking in Turkey, this study is the first study employing Nosich's (2011) opinions on critical thinking standards and critical thinking components as well as Paul's (1995) opinions on critical thinking virtues, and it offers an exemplary implementation for teachers.

Method

Research Design

In this study, a quasi-experimental model with pre-test-post-test control groups was applied. In the experimental group, the subject-based critical thinking education was applied to maths lesson for 2 hours per week for 16 weeks. However, in the control group, the current curriculum was applied.

Research Sample

The study was carried out on 6th-grade students studying at a state secondary school in the academic year 2015-2016 in Adana. Only volunteer students were involved in this study and the approvals of their parents were obtained. The students were divided into two groups as the experimental group (n=31) and the control group (n=31) after matching the students by using their grade point average in maths lessons, MCTT and CTVPS pre-test scores, and Personal Information Form results. The random assignment method was employed for the experimental and control groups.

Research Instruments, Validity and Reliability

The data collection instruments used in this study were MCTT, CTVPS, and Personal Information Form. The detailed information about the validity-reliability studies of these instruments are provided below.

Mathematical critical thinking test (MCTT). In this study, the literature reviews were performed by the researchers in order to assess the mathematical critical thinking skills of the students. In parallel with critical thinking components (purpose, question at issue, assumptions, implications and consequences, information, concepts, conclusions and interpretations, point of view, context, and alternatives) and standards (clearness, accuracy, importance-relevance, sufficiency, depth, breadth, and precision) taken as base in this study, the tentative forms containing open-ended questions that are suitable for the achievements of 6th-grade maths lessons and the readiness of students in math were established. After obtaining expert opinions, two separate forms were created to be used as pre-test (Form 1) and post-test (Form 2). In each form, a mathematical problem was presented to the students and they were asked to answer the questions prepared within the framework of critical thinking components (for example, "Other solutions I would suggest regarding the problem are as follows") and standards (for example, "What subject in mathematics does Ali need to know in order to solve this problem?"). The forms were applied to two different 6th grade groups of 30 students. There was a statistically significant relationship between the maths grades of students and the scores from their tentative forms, and there were .45 correlation with Form 1 and a .48 correlation with Form 2. According to these

results, it was determined that the MCTT forms are valid. In the analysis performed for reliability, the Cronbach Alpha values were found to be .74 for the MCTT Form 1 and .75 for the MCTT Form 2. Moreover, the data obtained from the tests were also rated by experts (a faculty member and a doctoral student trained in critical thinking) with MCTT Graded Rating Key, and the correlation between these scores was analysed. The correlation between these rates was significant at the level of .01 and there was a .95 correlation with Form 1 and a .98 correlation with Form 2. According to this result, it can be said that relationship between the scores is reliable. In order to rate the answers to these tests, a MCTT Graded Rating Key was prepared. The necessary literature reviews were made while preparing the MCTT Graded Rating Key (Butera, Friesen, Palmer, Lieber, Horn, Hanson & Czaja, 2014; Dogan-Dolapcioglu, 2015; Haladyna, 1997; Kitchener, 2008; Marcut, 2005; Saleh, 2009), the expert opinion was obtained, and the criteria were set in order to assess the answers to the open-ended questions of the MCTT at the four levels ("She/he expresses her/his thoughts completely and in accordance with the expected component/standard of critical thinking" Good-3 points, "She/he expresses her/his thoughts only incompletely in accordance with the expected component/standard of critical thinking" Moderate-2 points, "She/he expresses her/his thoughts in a way that does not conform to the expected component/standard of critical thinking." Improvable-1 point, and "She/he does not express her/his thoughts." Bad-0 points) for each of the critical thinking components and standards. In this scale, the minimum score in the MCTT is zero, whereas the maximum score is 51.

Critical thinking virtues perception scale (CTVPS). Literature reviews were made in order to determine the students' perceptions regarding critical thinking virtues and a 5-point Likert scale consisting of 58 items was prepared in parallel with the virtues of confidence in reason, intellectual perseverance, intellectual courage, and intellectual empathy among critical thinking virtues specified by Paul (1995). In this study, we specifically focused on these four virtues as we believed them to be the most suitable ones to be used in maths lessons. A 57-item tentative form, which was edited in parallel with expert opinions (faculty members in educational science, trained in critical thinking), was applied to 527 students, who were studying at 7th grade level, after obtaining the necessary approvals from their parents. After application, an exploratory factor analysis was performed on the data and a 4-factor structure explaining 43% of the total variance was adopted.

Table 1

Sub-dimensions of CTVPS and the number of items

Sub-dimensions	***Number of items***
Factor 1 (Confidence in Reason)	8 (1,3,6,7,8,13,15,22)
Factor 2 (Intellectual Perseverance)	6 (4,9,11,14,18,20)
Factor 3 (Intellectual Empathy)	7 (2,10,12,16,19,21,25)
Factor 4 (Intellectual Courage)	4 (5,17,23,24)
Total (F1, F2, F3, F4)	25

As seen in Table 1 above, there are eight items in the "Confidence in Reason (F1)" sub-scale and the factor loads of these items are between .520 and .686. There are six items in the "Intellectual Perseverance (F2)" sub-scale, and the factor loads of these items range between .596 and .744. There are seven items in the "Intellectual Empathy (F3)" sub-scale, and the factor loads of these items were between .501 and .658. There are four items in the "Intellectual Courage (F4)" sub-scale, and the factor loads of these items range between .465 and .716. For the significance level of .05, the correlations between the factors were found to be .09 (F1-F2), .42 (F1-F3), .24 (F1-F4), .22 (F2-F3), .40 (F2-F4), .35 (F3-F4), .59 (F1-CTVPS), .61 (F2-CTVPS), .77 (F3-CTVPS), and .74 (F4-CTVPS). It was determined that the sub-scales of CTVPS had a positive significant relationship with each other and with the total score. These results suggest that the scale has a strong factor structure and that it is valid. According to the results of the analyses made in terms of reliability, the Cronbach Alpha reliability coefficients were found to be .77 for F1, .79 for F2, .68 for F3, .63 for F4, and .83 for CTVPS. As stated by Buyukozturk (2007), the values equal to or higher than .70 are sufficient for considering the scale as a reliable one. Thus, in this case the scale was accepted to be reliable. The Split Half Analysis results also corroborate these results. In conclusion, the 5-point Likert-type 4-factor CTVPS consisting of 25 items (9 negative and 16 positive items) was prepared in order to assess the perceptions of students regarding critical thinking virtues. The minimum score in the scale was 25, whereas the maximum score was 125.

Personal information form. It was prepared by the researchers in order to determine if there is any significant differences between the groups in terms of socio-demographic characteristics.

Research Procedures

The curriculum formats were prepared in accordance with the 6th-grade math lesson achievements specified in the Secondary School Mathematical Applications Lesson Curriculum (MEB, 2014). The curriculum was prepared in parallel with the subject-based critical thinking education, the activities, questions, and materials in accordance to the critical thinking components and standards of Nosich (2011) and the intellectual courage, intellectual empathy, intellectual perseverance, and confidence in reason among critical thinking virtues of Paul (1995) were included. After obtaining expert opinions, the pilot application was performed. Considering the deficiencies and problems observed in the pilot application, the necessary measures were taken in order to prevent these problems from occurring in the future and the plans were reconsidered. In parallel with the pilot application in the first semester, measurement instruments were developed. After obtaining the necessary approvals, the main implementation was performed in the school, at which the first researcher is working at. The subject-based critical thinking education was applied to the experimental group. First, the students were informed about the concepts within the scope of critical thinking components, critical thinking standards, and critical thinking virtues, and several activities were conducted on how to apply these concepts to thought. For example, in an activity, the students were asked the question "Which profession will you choose in the future?". Students were asked to express the purpose of choosing

this profession, the questions they wonder about the profession, their assumptions, the implications and consequences related to this profession, what they know about the profession, the concepts they know about the profession, what conclusions they will meet when they have the profession, their point of view, and if any, alternatives for each component, and they were asked to express the context in which they realised their thoughts. These expressions were then presented in the classroom and it was determined whether the students' expressions met the critical thinking standards. When necessary, students were guided on how to apply these standards to their thinking. Later, the activities on mathematical problems and mathematical concepts in which students use critical thinking components and standards are included. Students were encouraged to share their thoughts with their friends and the class, and they were guided to develop intellectual virtues by creating frequent discussions. The current curriculum was taught in the control group. The data was collected by using pre-tests (MCTT Form 1, CTVPS) and the Personal Information Form applied at the beginning of second semester and the post-tests (MCTT Form 2, CTVPS) were applied at the end of the semester.

Data Analysis

The frequency and percentage values were calculated for the data obtained from the Personal Information Form, and a X^2 analysis was made. The mean and standard deviation values of the first term mathematics course grades were calculated and the Kruskal-Wallis H Test was used to determine whether there was a difference between the grade averages of the groups. Due to the normal distribution of the MCTT pre-test scores, whether there was a difference between the groups in terms of their pre-test scores was determined using a t-test analysis. It was observed that the CTVPS and subscales pre-test scores of the groups had deviations from the normal distribution, in this case, the Kruskal-Wallis H test, one of the non-parametric tests, was used to determine whether there was a statistically significant difference between the CTVPS pre-test scores of the groups. In addition, the arithmetic means of the MCTT and CTVPS pre-test-post-test scores, standard deviation values, post-test corrected mean scores, and standard error values were determined. Following this, a covariance analysis (ANCOVA) was performed for the post-test scores that were corrected according to the pre-test scores. The ANCOVA assumptions have been tested.

Results

The first question of this study was specified as follows: "Is there a significant difference between the post-test scores of the groups, when MCTT pre-test scores are controlled?" The arithmetic averages and standard deviation values of the MCTT pre-test-post-test scores of the groups and the corrected mean post-test scores and standard deviation values calculated in covariance analysis are presented in Table 2 below.

Table 2

Arithmetic Averages and Standard Deviation Values of MCTT Pre-test-Post-test Scores of the Groups and Corrected Average Posttest Scores and Standard Deviation Values

			Total Scores		Corrected Post-test Scores	
Groups	***N***		$\overline{X}$	**SD**	**Corrected** $\overline{X}$	**SH**
		Pre-test	24.26	6.89		
Exp.	31	Post-test	37.03	5.06	37.03	.70
		Pre-test	24.26	5.66		
Control	31	Post-test	29.00	3.75	28.97	.70

According to the results presented in Table 2 above, the corrected mean MCTT post-test score of the experimental group was found to be 37.03, whereas that of the control group was found to be 28.97. The results of 2x1 ANCOVA performed in order to determine if there was any significant differences between the groups', a MCTT post-test scores corrected for pre-test scores are presented in Table 3 below.

Table 3

ANCOVA Results of the Groups' MCTT Post-test Scores Corrected for Pre-test Scores

Source of Variance	**Sum of Squares**	**SD**	**Mean of Squares**	**F**	**Partial**	
					p	**η2**
Control Variable (Pre-test)	295.493	1	295.493	19.448	.00	.248
Main grouping effect	1008.065	1	1008.065	66.347	.00	.529
Error	896.442	59	15.194			
Total	2200.000	61				

As seen in Table 3 above, there was a statistically significant difference between the groups [F(1,59)= 66.347; *p*=.00]. This result suggests that the different educational methods applied in the groups affected the mathematical critical thinking abilities of the students differently. In this study, the amplitude of the effect on the total MCTT scores of students was measured using partial η2. While interpreting the amplitude of the effect, Stevens (1992) classified the effects as follows: those smaller than .01 have a small effect, .06 refers to a medium level of effect, and .14 refers to high level of effect (cited by Kandir, Yurt & Kalburan, 2012). Therefore, it can be seen that the method applied in the experimental group has a high level of effect (η^2=.529) on the mathematical critical thinking education. Within this context, it can be stated that, depending on the amplitude of effect, 53% of the change in the dependent variable is explained by the method applied. In conclusion, it was determined that the education applied in the experimental group is more effective on the mathematical critical thinking of students than the current curriculum.

The second question of this study was specified as follows: "Is there a significant difference between the post-test scores of the groups, when the CTVPS pre-test scores are controlled?" The arithmetic averages and standard deviation values of the CTVPS

pre-test-post-test scores of the groups, the corrected mean post-test scores, and the standard error values are presented in Table 4 below.

Table 4

Arithmetic Averages and Standard Deviation Values of CTVPS Pre-test-Post-test Scores of the Groups and Corrected Average Posttest Scores and Standard Error Values

CTVPS Sub-scales	Groups	*N*		Total Scores		Corrected Post-test Scores	
				$\overline{X}$	SD	Corrected $\overline{X}$	SE
Confidence in Reason	Exp.	31	Pre-test	36.48	2.67		
			Post-test	37.06	1.63	36.71	.218
	Control	31	Pre-test	35.16	3.33		
			Post-test	35.81	2.36	36.17	.218
Intellectual Perseverance	Exp.	31	Pre-test	26.10	4.09		
			Post-test	27.84	1.34	27.63	.225
	Control	31	Pre-test	24.19	4.15		
			Post-test	24.61	1.68	24.82	.225
Intellectual Empathy	Exp.	31	Pre-test	30.90	3.62		
			Post-test	32.84	1.49	33.02	.171
	Control	31	Pre-test	31.97	2.56		
			Post-test	31.45	1.36	31.27	.171
Intellectual Courage	Exp.	31	Pre-test	16.22	3.32		
			Post-test	17.55	1.71	17.65	.192
	Control	31	Pre-test	16.68	3.53		
			Post-test	16.87	2.09	16.77	.192
SCALE (General)	Exp.	31	Pre-test	109.71	10.2		
			Post-test	115.29	3.88	114.98	.388
	Control	31	Pre-test	108.00	8.47		
			Post-test	108.74	4.28	109.05	.388

In Table 4 above, it can be seen that the corrected CTVPS post-test mean scores of the groups are different from each other. The corrected post-test mean score of the experimental group in the "Confidence in Reason" subscale was 36.71, whereas that of the control group was 36.17. In the "Intellectual Perseverance" subscale, the corrected post-test mean score of the experimental group was calculated to be 27.63 and that of the control group to be 24.82. In the "Intellectual Empathy" subscale, the corrected post-test mean score of the experimental group was calculated to be 33.02 and that of the control group to be 31.27. In the "Intellectual Courage" subscale, the corrected mean post-test score of the experimental group was found to be 17.65, whereas that of the control group was found to be 16.77. The CTVPS corrected mean post-test score of the experimental group was found to be 114.98, whereas that of the control group was calculated to be 109.05. The results of the 2x1 ANCOVA performed in order to determine if there is any significant difference between the groups' CTVPS

and subscale post-test scores corrected for pre-test scores are presented in Table 5 below.

Table 5

ANCOVA Results of the Groups' CTVPS and Subscale Post-test Scores Corrected for Pre-test Scores

Source of Variance	Sum of Squares	SD	Mean of Squares	F	*p*	Partial η2
Preliminary confidence in reason	161.574	1	161.574	11.973	.00	.655
Main grouping effect	4.283	1	4.283	2.968	.09	.048
Error	85.136	59	1.443			
Total	271.242	61				
Preliminary intellectual perseverance	49.225	1	49.225	32.155	.00	.353
Main grouping effect	115.758	1	115.758	75.615	.00	.562
Error	90.323	59	1.531			
Total	300.839	61				
Preliminary intellectual empathy	69.175	1	69.175	77.451	.00	.568
Main grouping effect	46.185	1	46.185	51.710	.00	.467
Error	52.696	59	.893			
Total	151.694	61				
Preliminary intellectual courage	151.726	1	151.726	132.748	.00	.692
Main grouping effect	12.142	1	12.142	10.623	.00	.153
Error	67.435	59	1.143			
Total	226.274	61				
Preliminary CTVPS	727.478	1	727.478	156.165	.00	.726
Main grouping effect	540.429	1	540.429	116.012	.00	.663
Error	274.845	59	4.658			
Total	1666.984	61				

In Table 5 above, when the CTVPS pre-test total scores were controlled, there was a statistically significant difference between the groups in terms of the CTVPS post-test total scores [F(1,59)= 4.658; *p*=.00]. According to the results, it was determined that, when the Intellectual Perseverance (*p*=.00), Intellectual Empathy (*p*=.00), and Intellectual Courage (*p*=.00) subscales' pre-test total scores were controlled, there were statistically significant differences between the groups in terms of corrected total post-test scores. When the total pre-test score of the subscale Confidence in Reason (*p*=.09) was controlled, it was determined that there was no statistically significant difference between the groups in terms of corrected total post-test scores. Thus, it was determined that the education applied in the experimental group has a high level of effect on the students' perceptions about critical thinking virtues (η^2=.663). Within this context, it can be stated that, depending on the amplitude of effect, 66% of the change in the dependent variable is explained by the education applied. In conclusion, it was

determined that the education applied in the experimental group is more effective on the students' perceptions about critical thinking virtues than the current curriculum.

Discussion, Conclusion, and Recommendations

Firstly, in order to examine the effects of subject-based critical thinking education in the maths lessons on critical thinking skills of students, MCTT was applied to the groups as pre-test and post-test. According to the results of covariance analysis, a statistically significant difference was found in favour of the experimental group. It was determined that the education given in the study group positively affected critical thinking skills of the students.

In the literature, there are many studies and opinions corroborating this result. In the studies, in which the activities for critical thinking were used, it was reported that these activities contributed to the critical skills and predispositions of the students (Aybek, 2007; Hohmann & Grillo, 2014; Scanlan, 2006; Thomas, 1999; Yildirim, 2009; Yoldas, 2009). Again, the results obtained in the present study show similarities with the results obtained in most of the studies employing activities, methods, or subject-based critical thinking education in order to raise critical thinking in maths lessons (Brown, 2016; Hager, Sleet, Logon, & Hooper, 2003; Mintz, 2000; Palinussa 2013; Porter, 1998; Rice, 1992; Obay, 2009; Sezer, 2008). In these studies, it was reported that the problem-solving activities in the maths lessons played an effective role in developing critical thinking.

This study is based on critical thinking components were used for analysing thinking and critical thinking standards were used for assessing thinking. The activities of reasoning, estimating, analysing, questioning, and problem-solving were frequently employed, and different methods such as brainstorming, drama, and discussions were used. It can be stated that this procedure made students more active in maths lessons and improved their advanced thinking skills. Hence, in a study carried out by Preus (2012), it was observed that the advanced skills of students improved in lessons, in which the methods of asking open-ended questions, giving short texts, assigning tasks to the students, using visual sources, having discussions, and face-to-face explanations were used, and critical thinking skills of the students improved. Besides that, the works of pairs and groups were also employed. In previous studies, it was reported that critical thinking education involving group work improved critical thinking skills (Alkaya, 2006; Gokhale 1995; Kaasboll, 1998). Considering all of these, it can be said that subject-based critical thinking education used in the maths lessons positively contributed to critical thinking skills of the students. Second, the CTVPS was applied to the groups as pre-test and post-test in order to examine the effects subject-based critical thinking education had on students' critical thinking virtues. According to the results of the covariance analysis, a statistically significant difference was found between the groups in favour of the experimental group. At the same time, there was a statistically significant difference between the groups in favour of the experimental group in the sub-scales "Intellectual Perseverance", "Intellectual Empathy", and "Intellectual Courage". It was determined that, when the pre-test scores of the sub-scale "Confidence in Reason" were controlled,

there was no statistically significant differences between the post-test scores of the groups.

In this study, in which the subject-based critical thinking education program was implemented, the personality traits that a good thinker should have were explained and examples were given on how these personality traits reflect to behaviours. During the implementation, the students worked individually, in pairs, and in groups on complex problems and the activities were performed to get them to find all of the possible results and to choose the option which they think it might be the most accurate one, among them. At the end of the activities, the students were asked to define the problems they had while solving the problem, to express their reasoning, and to explain the discussions that were made on these subjects. It was observed that the students actively participated in the lessons, that they made an effort to solve a problem with their friends, and that they tried to solve the problems by thinking step-by-step and performing good thinking skills. Moreover, it was also determined that the students behaving impatiently in completing the activities and finding solutions for the problems left these behaviours in time and they started to allocate sufficient time to the activities and problems. Hence, Paul and Elder (2001) reported that the persons having intellectual perseverance reach a conclusion by performing methodical and careful reasoning regarding the complex subjects and problems. Considering these, it can be stated that the subject-based critical thinking education positively influenced the perception of the students on the virtue of Intellectual Perseverance.

Moreover, in this study, the roles of students that they played during pairwise and group works were changed and they were asked to think about things by considering other's perspectives and to summarise what others stated during the discussions. Furthermore, after the group works were carried out in the lesson, each of the students were asked to identify their contributions to the group work, the situations in which they diverged from their friends, their opinions about their group friends, and the disputes they had in the group and how these disputes affected them. Following this, each of the group members criticised these opinions. Paul and Elder (2001) emphasised that, to be a fair critical thinker, it is necessary to know the perspectives of others and to make an effort in good faith. During the observations in the lessons, it was determined that the students made an effort to understand their friends and that they accepted that they might make mistakes. Thus, it can be said that the subject-based critical thinking education positively influenced the perceptions of students in the experimental group on the virtue of Intellectual Empathy. Besides that, during the activities performed in individual and group works, the students were asked to determine their own beliefs and the beliefs of the group/class and to talk about and question these beliefs. The students were asked to determine the situations, on which they think differently from their friends, and to share these situations with their friends and to express how the reactions of others make these students feel. Some of the exemplary scenarios were acted out in the classroom and discussions were made on the reactions and thoughts of the students. It was observed that the students initially had difficulties in and were ashamed of expressing their thoughts. However, throughout the course of time, the students started to easily express their thoughts.

From this aspect, it can be said that critical thinking education positively affected the perceptions of students in the experimental group on the Intellectual Courage virtue.

In the present study, to realise and have confidence in their reasoning, the students were asked to explain their reasoning in the problem-solving process and were asked to realise how they reason by analysing the expressions they used when they need to advocate themselves during the discussions. Moreover, by talking about the reasoning of their friends, how their reasoning could be reasoned was discussed. The students were asked to compare their reasoning processes. These activities enabled the students in the experimental group, in which the subject-based critical thinking education was performed, to have awareness about intellectual reasoning. However, after analysing the results, it was determined that the perceptions of students in the experimental group on the virtue of Confidence in Reason were not statistically significantly different from those students in the control group. The reason for this may be that the current program applied in the control group was designed in a way of prioritising reasoning. The students in the control group might have enthusiastically solved the problems and used reasoning processes by actively participating in the lesson maybe because the activities in the current curriculum have been designed in a way that use reasoning processes and maybe if the problems have been related to daily life. From this aspect, it can be thought that there was no significant difference between the groups' perceptions on the Confidence in Reason virtue. In conclusion, when critical thinking virtues were considered together, the difference between the groups was in favour of the experimental group and this can be interpreted in a way that the subject-based critical thinking education applied in this study positively influenced the perceptions of students on critical thinking virtues.

In this study, the subject-based critical thinking education program applied in maths lessons aimed to give the students critical thinking skills and critical thinking virtues. The results obtained indicate that there is a statistically significant difference between the groups, in favour of the experimental group in terms of critical thinking skills and critical thinking virtues. The activities used by the teachers, which were designed based on the critical thinking, in the maths lessons positively contribute to students' critical thinking skills and critical thinking virtues. In order to perform subject-based critical thinking skills, the practitioners should firstly be good critical thinkers. For this reason, the teachers should improve themselves in terms of critical thinking, for example, they may attend seminars, in which they can learn how to apply critical thinking in their disciplines. Similar studies in different lessons and at different grades can be carried out. Furthermore, different scales and tests can be developed in those studies or the existing assessment instruments can be used. The effects of subject-based critical thinking education on different dependent variables can be analysed. Educating the individuals on having intellectual virtues gained more importance nowadays. For this reason, the studies carried out for longer periods can be designated to give students critical thinking virtues.

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Konu Temelli Eleştirel Düşünme Öğretiminin Matematik Dersinde Öğrencilerin Eleştirel Düşünme Becerileri ve Eleştirel Düşünme Erdemlerine Etkisi

Atıf:

Arisoy, B., & Aybek, B. (2021). The effects of subject-based critical thinking education in math on the students' critical thinking skills and virtues. *Eurasian Journal of Educational Research*, *92*, 99-120, DOI: 10.14689/ejer.2021.92.6

Özet

Problem Durumu: Bilim ve teknolojinin hızla geliştiği günümüz dünyasında iyi düşünebilen, problemlere etkili çözümler getirebilen, insan haklarına saygılı, topluma karşı sorumluluk duyan, yapıcı, yaratıcı, eleştirel düşünme becerilerine ve eleştirel düşünme erdemlerine sahip bireylere duyulan ihtiyaç giderek artmaktadır. Günümüz şartlarında eleştirel düşünmenin erken yaşlardan başlanarak eğitimin her kademesinde bireylere öğretilmesi gerekmektedir. Bazı araştırmacılar iyi bir eleştirel düşünme için iki koşul olduğunu belirtmektedir: Düşünme yansıtıcı olmalıdır, bu durumda eleştirel düşünme bileşenleri (amaç, konuyla alakalı soru, varsayımlar, uygulamalar ve sonuçları, bilgi, kavramlar, sonuçlar ve yorumlar, bakış açısı, bağlam, alternatifler) kullanılmalıdır. Aynı zamanda bu bileşenler eleştirel düşünme standartları (açıklık, doğruluk, önem-alakalılık, yeterlilik, derinlik, genişlik, kesinlik) ile değerlendirilmelidir. Bunun yanı sıra, eleştirel düşünme becerilerini sürekli olarak kullanmak ve bencilce kullanmamak için bireylerin eleştirel düşünme erdemlerine (entelektüel alçakgönüllülük, entelektüel cesaret, entelektüel empati, entelektüel dürüstlük, entelektüel azim, akıl yürütmeye güvenme, entelektüel özerklik, entelektüel tarafsızlık) sahip olması bir zorunluluktur.

Yapılandırmacı yaklaşımla birlikte eğitim sistemimizde daha çok önem kazanan "eleştirel düşünme" öğretim programlarında yer almasına rağmen, etkili bir şekilde öğretilememektedir. Nitekim bazı araştırmalar öğrencilerin eleştirel düşünme düzeylerinin yetersiz olduğunu göstermektedir. Bu durum öğretmen, öğrenciler, sınıfın fiziki şartları, öğretim programı, öğretim yöntemleri çeşitli nedenlerden kaynaklanabilmektedir. Bazı araştırmacılar eleştirel düşünme bileşenlerinin, standartlarının ve zihin özelliklerinin belirli disiplinler ve konu alanları içinde işlenmesinin, eleştirel düşünmenin öğretiminde daha etkili olduğunu ifade etmişlerdir. Düşünme becerilerinin etkin bir şekilde kullanıldığı matematik dersi, eleştirel düşünme ile birçok ortak noktaya sahiptir: İkisi de üst düzey zihinsel beceriler gerektirmektedir, her ikisi de dünyada olup bitenleri anlama ve problemlere çözüm bulma becerisi kazandırır. Ülkemizde konu temelli eleştirel düşünme öğretiminin, öğretim programlarında yer almasına rağmen, matematik derslerinde etkili bir şekilde gerçekleştirilemediği; bu alanda yapılan araştırmaların az sayıda olduğu tespit edilmiştir. Bununla birlikte araştırmalarda genellikle eleştirel düşünmenin beceri boyutuna vurgu yapıldığı, erdemler boyutunun çoğunlukla ihmal edildiği belirlenmiştir. Tüm bunlar göz önüne alındığında, eleştirel düşünme bileşenleri,

eleştirel düşünme standartları ve eleştirel düşünme erdemleri doğrultusunda planlanarak uygulanan matematik etkinliklerinin, öğrencilerin eleştirel düşünme becerilerinin ve eleştirel düşünme erdemlerinin geliştirilmesine olumlu yönde katkı sağlayacağı düşünülmektedir.

Araştırmanın Amacı: Bu araştırmanın amacı altıncı sınıf matematik dersinde gerçekleştirilen konu temelli eleştirel düşünme öğretiminin öğrencilerin eleştirel düşünme becerilerine ve eleştirel düşünme erdemlerine etkisini incelemektir.

Yöntem: Araştırmada nicel araştırma yöntemlerinden öntest-sontest kontrol gruplu yarı deneysel desen kullanılmıştır. Araştırma 2015-2016 eğitim öğretim yılında Adana'da bir devlet okulunda okumakta olan altıncı sınıf öğrencileriyle gerçekleştirilmiştir. Araştırmada bir deney (n=31) ve bir kontrol grubu (n=31) olmak üzere iki grup öğrenci yer almıştır. Öğrenciler altıncı sınıf matematik dersi birinci dönem not ortalamaları; Matematiksel Eleştirel Düşünme Testi (MEDT), Eleştirel Düşünme Erdemleri Algısı Ölçeği (EDEAÖ) öntest puanları ve Kişisel Bilgiler Formu sonuçlarına göre eşleştirildikten sonra deney ve kontrol gruplarına seçkisiz atama yöntemiyle atanmıştır. Deney grubunda eleştirel düşünme bileşenleri, eleştirel düşünme standartları ve eleştirel düşünme erdemleri kullanılarak hazırlanan ders planları Matematik Uygulamaları dersinde haftada iki saat olmak üzere 16 hafta boyunca uygulamaya konulmuştur. Kontrol grubunda ise mevcut program uygulanmıştır. Gruplara araştırmanın başlangıcında MEDT Form-1 ve EDEAÖ öntest olarak uygulanmıştır. Araştırmanın sonunda gruplara MEDT Form-2 ve EDEAÖ sontest olarak uygulanmıştır. Araştırmada kullanılan veri toplama araçları MEDT, EDEAÖ ve Kişisel Bilgiler Formu araştırmacılar tarafından geliştirilmiş olup, geçerlik güvenirlik çalışmaları yapılmıştır.

Bulgular: Gruplar arasında istatistiksel olarak anlamlı farklılık olup olmadığını belirlemek için MEDT ve EDEAÖ'den elde edilen veriler üzerinde kovaryans analizi (ANCOVA) yapılmıştır. Yapılan analizler sonucunda, konu temelli eleştirel düşünme öğretiminin uygulandığı deney grubu ile mevcut öğretim yönteminin uygulandığı kontrol grubu arasında;

- MEDT öntest puanları kontrol altına alındığında, sontest puanları açısından deney grubu lehine anlamlı farklılık bulunmuştur.
- EDEAÖ öntest puanları kontrol altına alındığında, sontest puanları açısından deney grubu lehine anlamlı farklılık bulunmuştur.

Sonuç ve Öneriler: Bu araştırmada, matematik dersinde gerçekleştirilen konu temelli eleştirel düşünme öğretimi ile öğrencilere eleştirel düşünme becerileri ve eleştirel düşünme erdemleri kazandırılmaya çalışılmıştır. Elde edilen bulgular sonucunda, eleştirel düşünme becerileri ve eleştirel düşünme erdemleri açısından gruplar arasında deney grubu lehine istatistiksel olarak anlamlı farklılık olduğu belirlenmiştir. Bu araştırma, matematik dersinde eleştirel düşünme becerileri ve eleştirel düşünme erdemlerini geliştirmeye yönelik örnek bir uygulama sunmaktadır. Derslerde eleştirel düşünmeyi temel alan etkinliklere yer verilmesinin öğrencilerin eleştirel düşünme becerilerini ve eleştirel düşünme erdemlerini geliştirmelerine katkı sağlayacağı

söylenebilir. Konu temelli eleştirel düşünme öğretimi gerçekleştirmek için öncelikle uygulayıcıların iyi birer eleştirel düşünür olması gerekmektedir. Bu bağlamda eğitici konumundaki kişilerin de eleştirel düşünme eğitimi almaları ve eleştirel düşünmeyi kendi alanlarına nasıl uygulayacaklarını öğrenecekleri seminerlere katılmaları önerilebilir. Farklı sınıf düzeylerinde ve farklı derslerde yapılacak benzer araştırmaların öğrencilerin eleştirel düşünme becerilerine ve eleştirel düşünme erdemlerine katkı sağlayacağı söylenebilir. Bu araştırmalar farklı ölçekler ve testler geliştirilerek veya halihazırda var olan başka ölçme araçları kullanılarak tekrarlanabilir. Benzer araştırmalarda, konu temelli eleştirel düşünme öğretiminin farklı bağımlı değişkenler üzerindeki etkileri incelenebilir. Örgün eğitimde araştırmalara ayrılan sürenin kısıtlı olması ve erdemlerin öğretiminin uzun süre gerektirmesi nedeniyle bu araştırma kapsamında sadece dört entelektüel erdeme (Entelektüel Azim, Entelektüel Empati ve Entelektüel Cesaret ve Akıl Yürütmeye Güvenme) yer verilmiştir. Entelektüel erdemlere sahip bireylerin yetiştirilmesinin önem kazandığı günümüzde, daha uzun süreli araştırmalarla öğrencilere eleştirel düşünme erdemlerini kazandırmak amacıyla bu tür araştırmalar tasarlanabilir.

Anahtar Sözcükler: Eleştirel düşünme bileşenleri, eleştirel düşünme standartları, eleştirel düşünme erdemleri, matematik eğitimi, ortaokul.