THE EFFECT OF DIFFERENTIATED MATHEMATICS PROGRAMS ON THE MATHEMATICS ATTITUDE OF GIFTED CHILDREN

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ABSTRACT

Mathematically gifted and talented students are different from other students when it comes to their needs and requirements. Therefore, it is necessary to develop and apply programs suitable for their readiness, interest and learning profiles. For this purpose, the aim of this study is to investigate the effect of a differentiated mathematics instruction program developed for gifted and talented students on their mathematical attitudes. In the study, "Mathematics Attitude Scale" developed by Baykul (1990) was used to measure the mathematics attitude of students in Turkey diagnosed as gifted and talented. The study was designed as a controlled pre-test post-test experimental study. The study sample consisted of twenty-four fifth grade gifted students, 12 children in the experimental and 12 in the control group. The statistical analysis of the data collected in the study was made using SPSS 16.0 and it was found that a differentiated mathematics teaching program prepared by the researcher increased the mathematics attitude of gifted and talented students.

Keywords: *Gifted and Talented Student, Differentiation, Mathematics, Mathematics Attitude.*

INTRODUCTION

Since the first half of the 20^{th} century, countries have begun to accelerate the education of gifted individuals in sports/arts and science and mathematics as a way of proving their superiority, and enabled these individuals to demonstrate their talents. Today, the development goals of many countries, including Turkey, include increasing the opportunities for gifted individuals to develop their own interests, talents, creativity, and enable them to become citizens beneficial to their countries and the world (Gifted Individuals Strategy and Implementation Plan 2013-2017). According to Robert J. Sternberg, superiority arises as a function of creativity while producing thoughts, analytical intelligence when evaluating the quality of thought, practical intelligence when implementing these thoughts, to convince others to value these thoughts and to follow them, and wisdom when it comes to guarantee that these decisions and their implementation is beneficial to the society. According to Sternberg, these features are not entirely hereditary; they also develop as a result of interaction with the environment (Sternberg, Jarvin, & Grigorenko, 2011). A more comprehensive definition is based on recent brain research. Brain research since the mid-1960s has shown that highly intelligent individuals are biologically different and that this difference is not entirely innate but rather originates from cellular changes that occur in the brain as a result of mutual interaction of genetic patterns and environmental opportunities. Furthermore, research data reveal that high intelligence level is a consequence of the development of the brain's primary functions. According to Clark (2002), based on these findings, high intelligence level appears as a result of the advanced and accelerated development of 4 functions of the brain called cognitive, emotional, physical (sensory, kinetic) and intuitive. According to him, the concept of intelligence and superiority can no longer be restricted only by the cognitive function of the brain; it should include all brain functions and their effective and integrated use.

When the characteristics of gifted students in mathematics are examined, they show features in the academic arena such as quick learning, sharp observation ability, strong questioning ability, extraordinary reasoning capacity, and creativity. In addition, students gifted in mathematics use fluid, flexible and creative ways while working with mathematical concepts (Sheffield, 2003) and tend to solve problems with flexible and creative solutions rather than using traditional methods (Gavin, 2009; Mcclure & Piggott, 2007; Miller, 1990; Souse, 2003).

As it can be seen, mathematically gifted students are different from other students in the classroom when it comes to their needs. The needs of mathematically gifted students have been tried to be met with services such as pull-out enrichment programs, moving up grades, starting school early, independent study and differentiation (Jordan, 2007 citing from Piirto, 1999). Due to the different developmental characteristics of these gifted students, their needs and requirements are also different. The fact that education programs are prepared according to the needs of average individuals also causes problems for gifted students in various points while developing their skills. These children need services beyond what is offered in differentiated education programs and regular school programs in order to be able to recognize their contributions to themselves and the society (Delisle & Galbraith, 2002). Therefore, it is necessary to establish curricula appropriate to the needs and requirements of these individuals (Assouline & Lupkowski-Shoplik, 2005; Clark, 1997; Clark, 2002; Davis & Rimm, 1998; Davis, 2006; Jordan, 2007; Stepanek, 1999; Tomlinson, 2001; Tomlinson & Strickland, 2005; Tomlinson et al., 2009; VanTassel-Baska & Stambaugh, 2008).

Most gifted and talented students still spend most of their school days in regular classes. The literature shows that there are specific educational strategies that can be used by regular classroom teachers to meet the needs of gifted students. Differentiation is the most recommended strategy in addition to acceleration, enrichment and grouping. Gifted and talented students are in need of a differentiated education program because they have different characteristics than their peers (Cash, 2017; Enç, 2004; Çepni, Gökdere, & Küçük, 2002; Davaslıgil & Leane, 2004; Deizmann & Watters, 2001; Davis & Rimm, 2004; Dreeszen, 2009; Hertberg-Davis, 2009; Kanlı, 2011; Kanevsky, 2011; Renzulli & Reis, 2004; Tekbaş & Ataman, 2004). Differentiated education is "a learning experience in which various methods are used so that students can explore the content of the program. Activities and processes are conducted towards meaningful learning, to enable students to uncover their own knowledge and ideas, and students are able to make choices for demonstrating and exhibiting what they learn" (Tomlinson, 2001). Tomlinson thinks that intelligence is fluent and that teachers need to develop different types of intelligence and guide their students towards effective learning (Jordan, 2007). Differentiation is an important and highly recommended strategy for meeting the needs of gifted students, especially in normal classrooms. Differentiation in the class may occur according to the needs of the child, the pace of the curriculum, or the depth of the curriculum. Tomlinson advises teachers to differentiate content, processes, or products based on student readiness, interests, and student profile (Tomlinson & Strickland, 2005). Readiness refers to a student's knowledge, understanding and talents in a particular learning sequence and may be influenced by factors such as previous experiences, approaches and mental habits. Interest refers to topics that the student is passionate about and interested in (Jordan, 2007). Students generally value more the subjects they are interested in. New, exciting and interesting subjects motivate students internally. In this context, teachers can shape education and training practices by determining activities that students can work on with interest (Sak, 2011). Learning profile expresses how the student best learns, his/her learning style, intelligence preference, culture and sex. The differentiated educational model is also important for the teacher while working with the entire class, to establish a sense of unity within groups, as it is often important to empower each student with their own understanding and abilities. Differentiated training provides multiple approaches to the content, process and product (Tomlinson, 2001).

As can be seen, there is a need for educational programs developed for gifted and talented students. It has been shown that affective input characteristics (interest, attitude, academic self) in Bloom's Full Learning Model explain 25% of the variance in success (Senemoğlu, 2010), and variables such as attitudes, anxiety, and academic self-perception are among the top of the affective variables associated with academic achievement (Valentine, DuBois, & Cooper, 2004; Pehlivan & ve Köseoğlu, 2010). Learning occurs in cognitive, affective (emotional) and psychomotor domains. Therefore, the personal and environmental factors affecting the learning of the student influence these three domains. Many studies to date have focused on the factors that affect cognitive learning. Therefore, studies on affective and psychomotor domians are rare (Çakır, Şahin, & Şahin, 2000). However, it is known that these three domains influence each other in learning and behavioural changes take place in all three domains. For all these reasons, the affective domain has recently been regarded as part of education as well as a focal point of research (Weinburg, 1995). Affective characteristics are "positive attitude towards mathematics, appreciation of its value, interest, motivation, anxiety about mathematics, and self-confidence features" (Baykul, 1992). It is seen that students with high mathematics achievement are more influenced by the attitude, method, teacher, family and environment factors than those with low mathematics achievement. Moreover, it is also found that the students who develop a positive attitude towards mathematics are more successful (Yenilmez & Duman, 2008). Gifted students have a higher mathematics aptitude compared to their normal peers (Koshy, Ernest, & Casey, 2009; Zimmerman, Bandura, & Martinez-Pons, 1992). However, they get bored in unsuitable educational environments, which negatively affect the attitudes of students towards the lessons (Gentry, Gable, & Springer, 2000). Gifted and talented students have a higher mathematics attitude compared to their normal peers but are also bored in educational environments that do not meet their needs. In this respect, it is thought that the results of this study will contribute to the international literature. In light of these, the aim of the study is to investigate the effect of a differentiated mathematics curriculum, developed on the basis of the characteristics and needs of gifted and talented students, on their mathematics attitudes. For this purpose, the following research questions were sought to be answered:

1. What are the students' mathematics attitudes scores?
2. Is there a difference between mathematics attitude pre-test scores of students?
3. Is there a difference between mathematics attitude post-test scores of students?
4. How is the mathematics attitude development of the control group students?
5. How is the mathematics attitude development of the experimental group students?

METHOD

In the study, pre-test post-test controlled experimental design was used (Balcı, 2011; Karasar, 2013). In the experimental group, mathematics was taught using a differentiated mathematics education program developed by the researcher, while in the control group the teaching was not interfered. In the study, the effect of learning with the help of a differentiated program on the mathematics attitude of gifted students was investigated.

Research Group

The study group consisted of 24 fifth grade students diagnosed as gifted students studying in a primary school, which provides formal education at primary level to gifted students in Turkey. A primary school has been assigned as a pilot school for the Education of Gifted Students Project implemented by a public university in Istanbul in accordance with the protocol signed between the Ministry of National Education and Istanbul University on June 30, 2002. In this school, gifted and talented students are educated with a program that meets their mental, emotional and social needs (Davaslıgil & Leane, 2004). To create the study groups, students were paired and separated into two groups, experimental and control groups. The distribution of the sample is given in Table 1.

Table 1
Gender of Students

Groups	Girl f	Girl %	Boy f	Boy %	Total
Experimental	3	25	9	75	12
Control	3	25	9	75	12
Total	6		18		24

Both the experimental group and control group consist of 3 girls (25%) and 9 boys (75%). The number of students in the groups and their gender distributions are the same as shown in Table 1.

Procedure

Two groups of previously diagnosed gifted students were matched according to their mathematics attitude scores, and separated into experimental and control groups. Before applying the differentiated mathematics program to the experimental group, necessary permissions were obtained from the Ministry of National Education. In this way, the students voluntarily participated in the research. In the research, the "Fractions" unit of the fifth-grade mathematics curriculum was used. When the fifth-grade achievements of the Turkish Ministry of Education on this topic are examined, the achievements were found to be significantly inadequate for gifted and talented students. While the program was being differentiated (content, process and product) the Grid Curriculum model developed by Kaplan (1986) and the Parallel Curriculum Model developed by Tomlinson et al. (2009) were used. In addition, while the activities were being organized, the teaching materials of the 'Fractions' sub-learning topic of the 'Numbers and Operations' learning topic within the M^3 (Mentoring Mathematical Minds) project developed under the leadership of Gavin, Sheffield, Chapin, and Dailey (2008) were used. The aim of the Grid Model developed by Kaplan, which is the first model on which the differentiation of the program was based, is to recognize the characteristics of gifted children, to support the development of these characteristics and to move them further. Basically, Grid is a model developed to construct the necessary elements and format for the differentiated curriculum (Kaplan, 1986). While the program was being prepared on the basis of the Principles of the Grid Model, a theme was selected first for content, process and product differentiation, and "Fractions" subject was placed on a theme when the content was prepared, as required by this model. Subjects were transposed within the scope of the selected 'Balance' theme and a more comprehensive course layout was provided. Educational programs for gifted students must include content and process goals as well as move in the same direction in the themes set out as goals (VanTassel-Baska, 1992). The subject of "Fractions" was handled together with Social Sciences, Music, Science and Turkish disciplines. The differentiations within the scope of the two models utilized towards the interests of the students were also addressed within the program. A learning environment was created with projects, discussions, and games based on the interests of the students. At the same time, the learning environment was also differentiated, organized in a flexible manner and designed to maximize their creativity. Instead of merely giving new information to the students through various activities, the process of acquiring new information was enriched, and the students were enabled to become productive individuals who can process abstract and complex thought, develop high-level thinking skills, produce knowledge, and provide new solutions to problems. Under the guidance of the researcher, students were given various research themes either individually or in small or large groups to improve their research skills, and then the presentations of these research themes were made.

Another model utilized while differentiating the program was the Parallel Education Model. As required by this model, activities were designed within the program in accordance with 'General Curriculum', 'Connections Curriculum', 'Practices Curriculum' and 'Identity Curriculum'. 'General Curriculum' is based on the main concepts, principles and skills of the discipline concerned (Tomlinson et al., 2009). In this differentiated program, which was built on the theme of 'balance', by accumulating the main concepts, principles and skills, connections were also established for meaningful learning of students. Activities were designed and implemented that focused on understanding instead of memorization, aim to solve problems by using creative and critical skills, and engage students emotionally as well as cognitively.

'Connections Curriculum' is designed to help learners see, learn and discover connections. Built on the core curriculum, it focuses on the main concepts, theories, principles and skills of a related discipline. It is also the goal of this curriculum to ensure the development of skills that the core curriculum does not include or emphasize. As mentioned earlier, the subject of 'Fraction' was taught in relation to Science, Social Studies, Turkish and Music courses. Two guest academicians (Architect and Music Educator) were invited to the learning environment. 'Connections Curriculum' was utilized as a result of students and these academicians working together in and out of the classroom in a master-apprentice fashion. The 'activities curriculum', one of the dimensions of 'parallel curriculum', is built on the core curriculum, and at the same time aims to take the core curriculum further by expanding the scope of individual achievements. The content of the activity is based on taking the basic knowledge learned by students' one step further, and using it in real life. The impacts of the subject on other fields are explained by activities such as 'What would happen if there were no fractions?', 'Find the business areas where fractions are used', 'Find the businesses where fractions are not used', 'Suppose that fractions never existed in our lives, think of alternative fields that we can use instead'. 'Awareness curriculum' is built on the core curriculum like other parallel items. It aims to help students identify themselves and their disciplines and associate themselves with disciplines. The evaluation of the prepared activities has been left to the students themselves and their friends. It is believed that these product evaluations also contribute to their positive attitude towards mathematics lessons. While preparing the program, the M^3 Project, developed under the leadership of Gavin et al. (2008), was also used in addition to the Grid and Parallel Curriculum Models mentioned above. Project M^3 contains teaching materials that promote learning by discovery while enabling students to like mathematics, think like real mathematicians, and reach rules by making inferences according to mathematical logic in many cases. The instructional materials consist of a student activity book, a teacher's handbook, activity cards and activity tools. The 'Deep Thinking' activities in the student's book, the 'activity cards' that make learning fun and educational, and 'activity tools' which concretize teaching and provide results with various logical conclusions were utilized from this teaching package in line with the principles of differentiation. 'Deep Thinking' is in the form of work sheets, and consists of activities that allow students to learn a subject deeper and more meaningfully. These activities allow students to make mathematical inferences and think like real mathematicians, and to think at a high level. 'Activity cards' are designed for individual and collaborative learning of students. Some include hints to facilitate learning at the beginning of the lesson, and some contain rules that reinforce learning at the end of the lesson. In this teaching material, the subject of fractions was examined in subheadings such as 'Equality', 'Fraction Types', 'Ranking in Fractions' and 'Addition and Subtraction in Fractions'. The differentiation of these subheadings was not considered sufficient for the application and the researcher added the subheadings 'Multiplication and Division in Fractions', 'Fraction Problems', 'Ratio' and 'Percentage' in addition to these. At the same time, activities were developed and implemented that were appropriate to their knowledge level and learning pace, attracted their attention, complex enough to allow them to learn information simultaneously rather than consecutively, and also enabling deep learning by allowing students to conduct in-depth studies like experts in special fields or topics they are interested in. The students in the control group continued normal education with their teachers without any interference. Mathematics Attitude Scale was used as the data collection tool, and applied to both groups as pre-test and post-test.

Data Collection Tool

The "Mathematics Attitude Scale" developed by Baykul (1990) was used in order to determine students' attitudes towards mathematics. "Mathematics Attitude Scale" consisted of 30 Likert-type questions with the choices of 'I absolutely disagree', 'I do not agree', 'Undecided', 'I agree' and 'I absolutely agree'. 15 positive questions were scored as 1, 2, 3, 4, 5 and 15 negative questions were reversely scored as 5, 4, 3, 2, and 1, respectively. The highest score that can be obtained from the Mathematics Attitude Scale is 150, and the lowest obtainable score is 30. The validity and reliability study of the scale was conducted by Baykul (1990), and the Cronbach's Alpha coefficient of the scale was found to be 0.96. The reliability coefficient of the scale was calculated as 0.96 in this study.

Data Analysis

Statistical analysis of the data collected in the study was made using SPSS 16.0. In the analysis of the data, nonparametric tests were used, taking into account that the number of data was less than 30 (Pallant, 2005). Mann Whitney-U test and Wilcoxon Signed Ranks Test were used in statistical analyses.

FINDINGS

Findings will be examined based on five questions that constitute the research problem. Findings of the first research question are shown in Table 2.

Table 2
Mathematics Attitude Scale Scores of Groups

Mathematics Attitude	N	X	Ss
Control Pre-test	12	117.33	29.40
Experimental Pre-test	12	108.16	26.55
Control Post-test	12	115.83	29.67
Experimental Post-test	12	117.75	26.66

The mean pre-test Mathematics Attitude Scale score of gifted and talented students in the experimental group was 108.16 and the mean post-test score was 117.75. The students who were in the control group had a pre-test score average of 117.33 and a post-test score average of 115.83. As can be seen, the average mathematics attitude score of the experimental group increased while the average score of the control group decreased (Table 2).

The findings of the second research question are given in Table 3.

Table 3
Mann-Whitney U Test Results According to Mathematics Attitude Scale Pre-test Scores

Mathematics Attitude pre-test	N	Mean Rank	Sum of Ranks	U	z	p
Control	12	14.38	172.50	49.500	-1.300	.194
Experimental	12	10.63	127.50			

There was no significant difference between mean Mathematics Attitude Scale pre-test scores of the groups ($U = 49.500$, $p > 0.05$). Based on this data, it can be said that the pre-test scores of the groups are equivalent.

The findings of the third research question are given in Table 4.

Table 4
Mann-Whitney U Test Results According to Mathematics Attitude Scale Post-test Scores

Mathematics Attitude Post-test	N	Mean Rank	Sum of Ranks	U	z	p
Control	12	12.46	149.50	71.500	-.029	.977
Experimental	12	12.54	150.50			

There was no significant difference between mean Mathematics Attitude Scale post-test scores of the groups (U = 71.500, p > 0.05).

The findings of the fourth research question are given in Table 5.

Table 5
Wilcoxon Test Results of the Control Group According to Mathematics Attitude Pre-Test and Post-Test Scores

	Ranks	N	Mean Rank	Sum of Ranks	Z	p
Control Pre-test - Post-test (Mathematics Attitude)	Negative Ranks	9	5.56	50.00	-.863	.388
	Positive Ranks	3	9.33	28.00		
	Ties	0				
	Total	12				

There was no significant difference between the Mathematics Attitude Pre-Test and Post-Test scores of the control group (z=-.863; *p*>.05) (Table 5). Based on this data, it can be said that traditional education does not increase the mathematics attitude of the students in the control group.

The findings of the fifth research question are given in Table 6.

Table 6
Wilcoxon Test Results of the Experimental Group According to Mathematics Attitude Pre-Test and Post-Test Scores

	Ranks	N	Mean Rank	Sum of Ranks	Z	p
Experimental Pre-test - Post-test (Mathematics Attitude)	Negative Ranks	0	.00	.00	-3.063	.002*
	Positive Ranks	12	6.50	78.00		
	Ties	0				
	Total	12				

*p<.05

A significant difference was found between the Mathematics Attitude Pre-Test and Post-Test scores of the experimental group (z=-3.063; *p*<.05) (Table 6). It can be said that the differentiated mathematics education increased mathematics attitudes of the students in the experimental group.

DISCUSSION

Based on findings, it is seen that the Mathematics Attitude Scale scores of gifted students in the experimental group increased after the differentiated mathematics program was applied, whereas the Mathematics Attitude Scale scores of students in the control group decreased. As can be seen, applying the regular curriculum to these gifted students causes their attitudes towards mathematics to decrease. Failure to apply instructional strategies such as differentiation can cause an affective decrease in mathematics attitudes of these students and regrettably, a decrease in their academic achievement. The increase in mathematics attitude scores in the experimental group in which differentiated mathematics teaching was applied reveals once again the necessity of programs tailored for the needs of gifted students. The high mathematics attitudes of students in the experimental group may be due to educational practices that meet their needs. Differentiation affects student achievement and learning attitudes (Brighton, Hertberg, Callahan, Tomlinson, & Moon, 2005). A study of 364 gifted and talented students selected at a centre with differentiation and acceleration practices also revealed a high mathematics attitude in these students (Martin, 2002).

There was no significant difference between the pre-test scores of the experimental and control group and pre-test post-test scores of the control group, but there was a significant difference between pre-test post-test scores of the experimental group in favour of the post-test. Based on these findings, it can be said that differentiated mathematics teaching is more effective than traditional teaching in having a positive effect on the mathematics attitudes of gifted students. Similarly, Boerger (2005) investigated the effects of differentiated education by using the station technique, and also reported that the students in the experimental group developed a positive attitude towards the mathematics lesson after the differentiated education application. In another study, the multi-faceted instructional technique of differentiated instructional design was discussed. In the experimental study which includes five-week multi-story teaching practice, it was concluded that students' academic achievement and attitudes towards mathematics fractions unit changed positively (Stager, 2007). Ozdemir and Kupcu (2010) investigated the effect of the use of individualized mathematics teaching materials on student achievement and attitude to mathematics lesson and it was concluded that their attitudes towards mathematics were positively increased in the experimental group where these materials were used. There are many studies showing that differentiation in mathematics teaching increases positive attitudes of students towards mathematics (Adelson & McCoach, 2011; Altıntaş, 2009; Barbato, 2000; Bosier, 2007; Dimitriadis, 2011; Hızlı, 2013; Martin, 2002; Özyaprak, 2015; Sheffield, 1999).

Just like all children, these children need families and especially teachers, who know that the students have similar needs around them, and who understand that they require certain tools to meet these needs (Silverman, 1992). Given the learning processes, it is understood that appropriate learning methods should also be used in the mathematics education of gifted students that allow them to be aware of their personal talents and enable them to improve their capacities and use that capacity at the highest level (Şenol, 2011).

CONCLUSION

In conclusion, it was seen that the applied differentiated mathematics program increased the scores of the experimental group, and the scores of the control group which continued education with the regular curriculum decreased in the post-test. This result suggests that the lack of an educational environment appropriate for the level of this group with different characteristics and educational needs causes a decrease in mathematics attitudes ultimately affecting academic achievement. It can be said that educational environments prepared according to their skills and abilities have a positive effect on the cognitive and emotional development of gifted and talented students. It is therefore imperative that curricula should be designed specifically for these students whose learning speeds differ from those of normal students.

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