Altering depth and complexity in the science curriculum for the gifted: results of an experiment

Burcu Seher ÇALIKOĞLU

Biruni University, Faculty of Education, Department of Gifted and Talented Education, 34010 Topkapı, Istanbul, TURKEY

E-mail: bscalikoglu2758@gmail.com

Nihat Gürel KAHVECİ

Istanbul University, Hasan Ali Yücel College of Education, Department of Gifted and Talented Education, 34452 Beyazıt, Fatih, Istanbul, TURKEY

E-mail: nkahveci@istanbul.edu.tr

Received 15 Jul., 2014
Revised 17 Mar., 2015

Contents

Abstract

The Republic of Turkey has developed democratic support for equity in education for groups who have various learning needs (Levent, 2011, p. 89-91). In connection with Turkey's central policy of education, current educational applications have addressed these diverse needs to a certain extent. Sak (2011) drew our attention to the insufficiency of gifted education at the primary school level by reporting that "Except in the Science and Art Centers affiliated with the Ministry of National Education and the curricular practices of Anatolian and Istanbul Universities, there are few local services for gifted students in Turkey" (p. 214-215).

Although partial and fragmented educational services for gifted students have been expanding in Turkey, gifted students are exposed to the same educational programs as the general student population as required by central education policies. In contrast with this policy, there is a widely accepted belief that gifted students should be educated differently from non-gifted students, based on the fact that the general curriculum is not challenging enough to serve their academic needs (Jonassen & Gabrowski, 1993, p. 310; Tokotro & Steels, 2004, p. 140-141; Tomlinson, Kaplan, Renzulli et al., 2001, p. 13). When Turkey's central education policy is taken into consideration, differentiating the general educational programs without changing their scope seems to be an appropriate way to increase the level of challenge.

Differentiation, i.e., modifying the program to align it with the student's characteristics, has long been an accepted approach in gifted and talented education (Tomlinson & Jarvis, 2000, p. 600). In seeking what matters in terms of a satisfactory level of challenge, depth and complexity are referred to as two developmental characteristics for actualizing one's potential and acquiring an academic identity. Therefore, there is broad agreement in the Turkish educational community that studies are needed to identify the types of differentiation that can improve outcomes for gifted students. This study helps to fill that gap by reporting on an experiment that differentiated a 5th-grade science curriculum in terms of depth and complexity.

Theoretical Background

Educational services to meet the academic needs of gifted students have generally been constructed based on the approaches of acceleration and enrichment. It is not a coincidence that these approaches have been developed in response to two distinct characteristics of gifted students: the pace and quality of learning. In contrast with acceleration, enrichment does not speed up the pace of the curriculum but instead intends to develop the quality of the curriculum and afford students a richer educational experience (Clark, 2008, p. 407-411; Schiever & Maker, 2003, p. 164-165). Reasoning at a more advanced level (Silverman, 1993, p. 54) and making better connections among separate ideas (Clark, 2008, p. 293; Gallagher & Gallagher, 1994, p. 85) are crucial characteristics of the gifted and suggest a need to incorporate features of depth and complexity into the core curriculum.

Existing gifted programs generally accentuate high levels of thinking of various emphases and in various manners corresponding to the goals of the program. Whereas the Integrated Curriculum Model (VanTassel-Baska & Wood, 2009, pp. 655-693) and Parallel Curriculum Model (Tomlinson, 2009, pp. 571-599) emphasize integrated thinking among or within the disciplines, The Study of Mathematically Precocious Youth (Stanley & Benbow, 1983) and Iowa Excellence Program for high school students (Assouline, Blando, Croft, Baldus and Colengole, 2009, pp. 1-17) emphasize academic acceleration. Whereas the Enrichment Triad Model (Reis and Renzulli, 2009, pp. 323-353) and The Autonomous Learner Model for the Gifted and Talented (Betts & Kercher, 2009, pp. 49-105) emphasize actualizing potential outside of the school context, the Purdue Three-Stage Model (Moon, Kolloff, Robinson, Dixon & Feldhusen, 2009, pp. 289-323) stresses critical and creative thinking skills that can be integrated into the core curriculum.

Depth and complexity are two approaches that can be embedded in any thinking skill to increase the quality or the level of thinking process. To put it differently, a higher level of thinking skills and depth and complexity are not completely unrelated constructs. However, their conceptual interrelationship makes it difficult to sort out the constructs of depth and complexity from the existing gifted programs unless their roles are stated conceptually or operationally by the program developer.

Kaplan (2009) disambiguated these constructs in her model to guide practical applications in gifted education. The author set forth the prompts of depth and complexity and their corresponding icons, definitions and sample questions. Depth prompts consist of the language of the discipline (nomenclature, lexicon or vocabulary of the study-What terms or words are specific to the work of the disciplinarian?); details (traits, attributes, characteristics to describe something-What features characterize this?); patterns (recurring events-What was the order of events?); unanswered questions (influences or forces that shape ideas-What is still not understood about this area, topic, study or discipline?); rules (stated or unstated reasons or explanations-How is this structured?); ethics (dilemmas, controversies, issues-What dilemmas or controversies are involved in this area, topic, study, or discipline?); and big ideas (generalizations, principles and theories-What general statement includes what is being studied?). Complexity prompts consist of over time (past, present, future happenings-How has time affected the information?); points of view (perspective, opinion-What are the opposite viewpoints?); and inter-disciplinary (connections between and across the disciplines-How are these ideas related or connected? (p. 242).

Dodds (2010) performed research on 88 gifted and 88 non-gifted students in the 3rd, 4th and 5th grades who were instructed by teachers trained in the use of these prompts of depth and complexity. He measured the depth and level of complex understanding of the participants in autumn 2008 as a pretest and in spring 2009 as a posttest. After evaluating the results, he concluded that (1) instruction focused on the prompts of depth and complexity developed the levels of understanding of both gifted and non-gifted students, (2) the level of understanding of the gifted students improved more than that of the non-gifted, and (3) gifted and non-gifted students found prompts of depth and complexity to be useful, interesting and challenging.

Depth

In the context of the study, depth is defined as understanding core meanings by building causal connections among events or situations (Egan, 2010; Lehrer, 2001, Jensen & Nickelsen, 2008; Kaplan, 2009; Salmon, 1998; VanTassel-Baska & Stambaugh, 2006). One of Gowin's (1970) observations in school science laboratories is that students are occupied with observing, making records and transforming data to tables, diagrams and graphics. During these activities, however, an essential aim can be neglected, that of the need to refer to concepts, principles and theories to grasp their underlying reasons (as cited in Novak & Gowin, 1984, p. 56-58). From Gowin's standpoint, actions dealing with operations more than explanations draw a line between depth and superficiality. Reasons establishes deeper understanding for the happenings around the environment. Assume that a student is confronted with a person who has an allergic of butter. If he concludes that some people has allergy, some people do not, this conclusion seems superficial compared to an effort to understand what makes his body allergic to butter.

Complexity

Understanding, as described by Gallagher (as cited in Folk, 2006, p. 29), can never be complete and can always be enriched and expanded with the formation of new meanings over time. Complexity suggests possibilities and multiplicity in thinking so that comprehension can be extended to new dimensions. In this respect, as the level of complexity increases, the relationships among components increase (Pollock, Chandler, & Sweller, 2002, p. 64). In such processes, as van Merrienboer and Sweller (2005, p. 148-149) explained, an individual is forced to handle a considerable number of simultaneous multiple processes. Several components of knowledge being used simultaneously increases the load of knowledge and processes in the working memory, which activates mental accumulation (van Merrienboer, Kirschner, & Kester, 2003, p. 9). Nonetheless, it should be noted that the primary purpose in complexity is not to expand knowledge by absorbing a surplus of facts and ideas but to simplify meanings by developing relationships among them. This interpretation supports the discussions in the studies of Clark (2008, p. 293), Kaplan (2009), van Merrienboer and Kirschner (2007) and VanTassel-Baska and Stambaugh (2006). The construct of complexity may be described as establishing different relationships among the variables to shift an individual's understanding into a more general one.

Depth and Complexity in Science

As explained in earlier subsections, depth and complexity are distinguished by their way of channeling thinking processes. Although depth and complexity may be described differently, the relationship between these constructs should not be overlooked. Grotzer's (2005, p. 3) clarifications indicate that these constructs are closely intertwined. When establishing causal relations in a situation lacking complexity, there are specific flawed assumptions one might rely on erroneously. Students seeking more explicit causes and effects fail to notice the role that passive agents, cannot be easily detected, but having casual connection with the happening in some way, play in scientific explanations. Specifically, Resnick (1996) concluded that students think of causality as being centered and deterministic rather than distributed and probabilistic. On this basis, it can be claimed that the intertwined relationship between depth and complexity in science is due to two underlying principles:

- Scientific explanations basically require causality among the associations of objects (Salmon, 1998, p.5).
- Events are not limited to one natural occurrence but should be observed in a larger network of a system (Page, 2011; Taylor, 2003).

The results of Dodds' findings suggest promise in the use of depth and complexity in gifted education. However, other than Kaplan's and Dodds' studies, there appears to be a lack of studies in the literature focusing on the use of these constructs in the education of gifted students. The scarcity of studies regarding depth and complexity in the role of gifted education suggests a need to explore these constructs both theoretically and experimentally. The current experimental study was conducted with the aim of demonstrating the use of depth and complexity in science education to attain a high level of achievement.

This study aimed at examining the effects of using a science curriculum differentiated in terms of the depth and complexity with gifted 5th-grade students. The effectiveness of this differentiated science curriculum as designed by the researcher was evaluated against three criteria: academic achievement, science process skills and attitude toward science education.

Given the importance of depth and complexity, this study seeks to answer the following question. What are the impacts, in terms of (a) academic achievement, (b) scientific process skills, and (c) attitude toward science education, of instructing gifted students using a science curriculum differentiated on the basis of depth and complexity versus instructing gifted students using a general science curriculum?

Methodology

Design

The experimental research was conducted to develop conclusions regarding the causal impact of an intervention by comparing a treatment group against a control group (Borg, Gall & Gall, 1993, p. 298). As summarized in Table 1, this study was based on the pretest-posttest control group design. This experimental design involved two matched groups, which were randomly designated the treatment and control groups. Both groups were administered a pre-test, received different educational programs and were administered a post-test.

Table 1. Design of the research study

Groups	Assignment	Pretests	Treatment	Posttests
Treatment	Random	AA SPS ATSE	Differentiated	AA SPS ATSE
Control	Random	AA SPS ATSE	General	AA SPS ATSE

Note. AA: academic achievement; SPS: Science Process Skills; ATSE: scale of attitude toward science education

Participants

The participants in the study consisted of 21 gifted 5th-grade students between 10 and 11 years old attending a primary project school affiliated with Istanbul University and the Ministry of National Education located in Istanbul, Turkey. Selected students at the project school were identified as gifted using intelligence tests administered by the Counseling and Research Center and confirmed by the Science Committee of the Project Executive Board. There are two classes in each grade, consisting of 24 students in each class. Half of each class consists of gifted students, and the other half consists of undiagnosed students. The project school serves both the gifted and non-gifted and was founded in 2002 with the aim of achieving social, emotional and academic gains in both groups of learners (Davaslıgil & Leana, 2004, p. 96-97). In line with the purpose of this study, non-gifted students at the project school were excluded from both the treatment and control groups.

Instruments

Academic achievement test. An academic achievement test was designed by the researcher to assess the participants' deep and complex understanding of the 5th-grade science curriculum, specifically the unit "Exploring and Getting to Know the World of Living Things". Forty-four items were developed on the basis of differentiated curriculum objectives and possessed the characteristics of both depth and complexity (see Appendix A). The items were submitted to five judges for review in terms of their scientific, psychometric and grammatical aspects. Flawed items were either corrected or replaced with new items.

In addition to the accuracy of the items, they were reviewed as to whether they served the purpose of the study. Three independent judges who were experts in science education were asked if the items were appropriate for evaluating the objectives of a differentiated curriculum developed on the basis of depth and complexity. They rated the items on a scale ranging from 'highly disagree' (1) to 'highly agree' (5). The average scores of the three judges were 4.77; 4.48; and 4.59 on a five-point scale. The average inter-judge reliability (Spearman Rho) coefficient was found to be .998. This high consensus among the judges also provided evidence of the content validity of the academic achievement test.

To evaluate the reliability and validity of the academic achievement test, 44 items were administered to 4th and 6th gifted graders in order to decide if questions are suitable for the 5th gifted graders. The administration of the achievement test to 4th and 6th grades had to be preferred by the author because of the limitation of time. The achievement test should be ready before the experimentally designed research was conducted and 5th grade gifted students were not taught the subject-matter while the test was being administrated. Besides this limitation, there is an advantage of this use in Turkey. In our country, Turkish educational system follows a spiral curriculum which means 4th and 6th graders were familiar with the concepts at varying degrees. Logically, 5th gifted graders' understanding of those had to be somewhere between 4th and 6th gifted graders.

191 gifted 4th and 6th graders who enrolled in the Science and Art Centers after-school programs for the gifted in İstanbul, Ankara and Adana. In these centers, because there are fewer 6th graders than 4th graders, 79 gifted 4th graders in the initial sample had to be randomly eliminated. The results were 56 gifted 4th graders and 56 gifted 6th graders, whose characteristics were analyzed using a software program. According to the discrimination indices, 10 items that did not meet the criteria were discarded. The remaining items constituted the 34 items on the academic achievement test.

The Cronbach Alpha coefficient, a measure of reliability, was found to be 0.78. The evidence for criterion validity was obtained by calculating the correlation coefficients between the scores on the academic achievement test and the students' fall semester grades in science education. The correlation coefficient for the 4th graders was found to be 0.14. The low relationship between the test scores and the grades of the 4th graders was expected because the 4th-grade students had not yet been taught the particular curriculum unit. In addition, their grades in science were generally high (average of 97.37; sd of 3.35). The correlation coefficient of 0.39 for the scores of the 6th graders on the academic achievement test can be considered satisfactory when taking into account the standard learning environment. As discussed earlier, in the introduction, these students are not necessarily offered a rich learning environment as a consequence of the attention placed on the needs of the average students. The 6th graders have been taught the subject matter in non-differentiated classrooms. This situation may explain the difficulty of the students experienced acquiring the content without differentiation.

Scientific process skills test. The Scientific Process Skills Test used in this study was originally developed by Burns, Okey, and Wise (1985) with the aim of measuring scientific process skills at the middle- and high-school levels. The 36 items in the Scientific Process Skills Test were translated into Turkish by Geban, Aşkar and Özkan (1992). Çakar (2008, p. 61) revised the test to improve its usability at the 5th-grade level by reducing the number of items from 36 to 24 with the help of three experts and a group of classroom teachers. The KR-20 reliability coefficient of the test was found to be 0.86. The average difficulty index was 0,58.

Scale of attitudes toward science education. The attitude scale used in this study was the Scale of Attitude toward Science and Technology Instruction developed by Nuhoğlu (2008). To evaluate the content validity, the items in this scale were revised by ten primary school teachers and six academicians at the department of primary school education. Three linguists checked the clarity of the language used in the scale. The three-point Likert scale was administered to 422 students in three primary schools in Üsküdar, İstanbul. The data were analyzed using the SPSS program. After performing the factor analysis, 10 of the 30 items were discarded. The resulting test included 10 negatively worded and 10 positively worded items. The Cronbach Alpha internal integrity coefficient was 0.87.

Copies of all the instruments are available from the authors on request.

Procedure

Groups. At the beginning of spring semester of the 2012-2013 academic year, 21 gifted 5th graders were administered the pre-tests of academic achievement, science process skills and attitude. After the pre-testing, students were assigned to two groups based on their (1) pretest scores, (2) fall-semester grades in science and (3) gender. The Mann Whitney U Test was used to check whether the two groups differed in terms of these variables. As shown in Table 2, there was no significant difference between the two groups at the level of 0.05. The groups were randomly designated the control group (n=10) and treatment group (n=11).

Table 2. Results of the Mann Whitney U Test Regarding the Grades and Pre Test Scores of the Treatment and Control Groups

Pre Tests	Groups	N	Mean Rank	Sum of Ranks	U	Z	p
Grades	Treatment	11	11.68	128.5	47.5	-.530	.590
	Control	10	10.25	102.5			
AA	Treatment	11	11.05	121.5	54.5	-.035	.972
	Control	10	10.95	109.5			
SPS	Treatment	11	9.64	106	40	-1.059	.289
	Control	10	12.50	125			
ATSE	Treatment	11	11.27	124	52	-.212	.832
	Control	10	10.70	107			

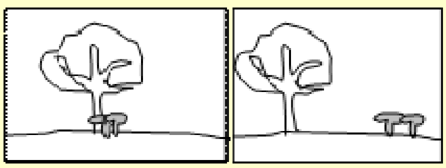
Differentiation. By modifying the general curriculum on the basis of depth and complexity, the differentiated and the general curriculum were made distinct from the standpoints of quality and level.

Quality of the content. Although the number of general curriculum objectives was reduced from 31 to 22, the meanings of general curriculum objectives were intensified by placing an emphasis on causality and were broadened by structuring a set of relationships. The differentiated content was organized around the theme of the system. This process established six categories of knowledge elements: 'theme', 'principles', 'topics', 'big concepts', 'associations', and 'curriculum objectives'. These knowledge elements were hierarchically designed and interrelated. For example, under the theme of "system", one of the differentiated curriculum objectives is "Students are able to explain the reason why vertebrae are a criterion used to classify animals by observing the features of vertebrates and invertebrates." This curriculum objective has a connection with an association of "the similarities and differences", which is related to the topic of "classes and species". This topic is tied to a principle, namely that "A system consists of various components" (see Appendix B).

Quality in process skills. Turkish policy in the development of a national science curriculum generally meets the need of acquiring scientific process skills within various contexts and at different time intervals (Ministry of National Education [MoNE], 2005, p. 5). Aside from the National Science Educational Programs, additional scientific process skills are embedded to support a differentiated curriculum in terms of the constructs of depth and complexity: (a) to achieve a level of depth, students are guided to decide themselves by which strategy or method to develop explanations for facts, events and phenomena; and (b) to achieve a level of complexity, students are challenged to understand how scientific strategies and methods in the design, implementation and evaluation of scientific investigations are related to one another.

Level. Through modifications, the differentiated science curriculum was upgraded from a knowledge of classifications and categories at the understanding level to a knowledge of principles and generalizations at the analysis level (Anderson et al., 2001; see Appendix C). The sample activity shown in Table 3 provides insight into the differentiation of the science curriculum on the basis of depth and complexity: While students were forced to think about the core concept, they needed to pay attention to the range of possible explanations.

Table 3. An excerpt from the differentiated science and technology curriculum

Objective	Students will be able to explain why mushrooms are not classified as plants.
Preparation	A few empty frames are drawn on the board.
Arousal of attention	Students are asked to draw a picture of soil, a tree and a group of mushrooms within the frame. (While most of the students draw in their notebooks, a few volunteers can draw on the board.)
Reflection	Two pictures drawn on the board are referred to while asking students the question "Which one of the pictures reflects reality more accurately?" 
Motivation	After taking a poll of the students, the correct answer is shared.
Challenge	By indicating the right picture, students are asked the question "How do you explain that mushrooms are in a different classification of living creatures, not animals and not plants, using this picture?" (Students are allowed to use their textbooks.)

Implementation. While the treatment group was offered the differentiated science curriculum by the researcher, the control group continued to be taught by their science teacher using the general science curriculum which is defined by National Ministry of Education. There is actually no extra core curriculum studies specific to gifted students in National Ministry of Education. See Appendix C for the comparisons between standardized science curriculum and the differentiated.

All the sessions in both groups were held in a classroom equipped with technological devices (a computer, a projector and a loudspeaker). Students' science teacher was not informed about the experimental design. Daily instruction was provided in two 40-minute periods over a span of 4 weeks. After each group completed the program, the participants in the study were administered the academic achievement test, the Science Process Skills Test and the attitude scale as post tests. The administration of the tests spanned two class periods (2x40 min.).

Method of Analysis

The data obtained from the scores on the academic achievement test, the Science Process Skills Test and the attitude scale were analyzed with the aid of SPSS software, version 15. Nonparametric order statistics was used in compliance with the purpose of the study. The Mann Whitney U Test was performed to determine whether the mean results from the treatment and control groups differ significantly (Edwards, 1960, p. 417), and the Wilcoxon Signed Rank Test was used to compare the pre- and post-test samples (Hays, 1963, p. 635).

Results

Academic Achievement

Table 4 shows that the difference in academic achievement between the pre- and post-test scores in the treatment group was significantly in favor of the post test at the 0.05 level ($z=-2.81$, $p<0.05$, $r=-0.88$). A similar result was not found among gifted students in the control group ($z=-1.78$, $p>0.05$, $r=-0.59$).

Table 4. Results of the Wilcoxon Signed Rank Test Regarding Academic Achievement Pre and Post Test Scores of the Treatment and Control Groups

Groups	Pretest-Posttest	N	Mean Rank	Sum of Ranks	Z	p
Treatment	Negative Ranks	0	0	0	-2.81	.005
	Positive Ranks	10	5.5	55		
	Ties	0				
	Total	10				
Control	Negative Ranks	2	3.75	7.5	-1.78	.075
	Positive Ranks	7	5.36	37.5		
	Ties	0				
	Total	9				

Note. *p < .05, two tailed.

Table 5 shows that the difference in the academic achievement post-test scores between the two groups was found to be significant at the 0.05 level in favor of the treatment group (z=-2.084, p<0.05, r=-0.64).

Table 5. Results of the Mann Whitney U Test Regarding the Academic Achievement Post Test Scores of the Treatment and Control Groups

AA Post Test Scores	N	Mean Rank	Sum of Ranks	U	Z	p
Treatment	10	12.5	125	20	-2.048	.041
Control	9	7.22	65			

Note. *p < .05, two tailed.

Scientific Process Skills

Table 6 shows that the difference between the scores of the treatment group was significantly in favor of post test at the 0.05 level (z=-2.82, p<0.05, r=-0.89); however, a similar result was not found among the participants in the control group (z=-.120, p>0.05, r=-0.04).

Table 6. Results of the Wilcoxon Signed Rank Test Regarding the Scientific Process Skills Pre and Post Test Scores of the Treatment and Control Groups

Groups	Pretest-Posttest	N	Mean Rank	Sum of Ranks	Z	p
Treatment	Negative Ranks	0	0	0	-2.823	.005*
	Positive Ranks	10	5.5	55		
	Ties	0				
	Total	10				
Control	Negative Ranks	3	7.17	21.5	-.120	.905
	Positive Ranks	6	3.92	23.5		
	Ties	0				
	Total	9				

Note. **p* < .05, two tailed.

Table 7 shows the difference in the scores between the two groups was found to be significant at the 0.05 level in favor of the treatment group (z=-1.98, p<0.05, r=-0.62).

Table 7. Results of the Mann Whitney U Test Regarding the Scientific Process Skills Post Test Scores of the Treatment and Control Groups

SPS Post Test Scores	N	Mean Rank	Sum of Ranks	U	Z	p
Treatment	10	12.4	124	21	-1.98	.047*
Control	9	7.33	65			

Note. **p* < .05, two tailed.

Attitude toward Science education

Table 8 shows that the difference between the scores of the treatment group was significantly in favor of the post test at the 0.05 level (z=-2,25, p<0.05, r=-0.75), and a similar result was found in the control group (z=-2.53, p<0.05, r=-0.84).

Table 8. Results of the Wilcoxon Signed Rank Test Regarding the Attitude Scale toward Science and Technology Course Pre and Post Test Scores of the Treatment and Control Groups

Groups	Pretest-Posttest	N	Mean Rank	Sum of Ranks	Z	p
Treatment	Negative Ranks	1	2.00	2.00	-2.25	.024*
	Positive Ranks	7	4.86	34.00		
	Ties	1				
	Total	9[a]				
Control	Negative Ranks	0	0	0	-2.53	.011*
	Positive Ranks	8	4.50	36		
	Ties	1				
	Total	9				

Note. [a]One student in the treatment group did not want to be tested on the attitude scale.
*p < .05, two tailed.

Table 9 shows that the difference in the scores between the two groups was not significant at the 0.05 level in favor of either the treatment group or the control group (z=-1.06, p>0.05, r=-0.35).

Table 9. Results of the Mann Whitney U Test Regarding Attitude Scale toward the Science and Technology Course Post Test Scores of the Treatment and Control Groups

SPS Post Test Scores	N	Mean Rank	Sum of Ranks	U	Z	p
Treatment	9	8.11	73	28	-1.06	0.29
Control	9	10.99	98			

Conclusions and Discussions

Academic Achievement

While the difference between the pre and post academic achievement test scores was significant in favor of the treatment group in the post test (z=-2.81, p<0.05), a similar result was not found in the control group (z=-1.782, p>0.05). This result can be attributed to the features of depth and complexity, which provided differentiation in the science and technology curriculum used by the treatment group.

Meaning is always context-bounded (Novak, 1998, p. 37). Although using knowledge at a high level of thinking is a part of intellectual ability, having a high level of mental ability does not necessarily lead to internalization in higher-level contexts (Perkins & Salomon, 1989). While taking the post test, the students in the control group might have had to (a) adapt to being confronted with new conditions and (b) reorganize their existing knowledge accordingly (Attewell, 1992; Haskell, 2001, p. 24; Kogut & Zander, 1992). In other words, the students in the control group might have had difficulty transferring their knowledge from traditional contexts to more deep and complex contexts while taking the post test. This conclusion is supported by findings by Carr, Alexander, Schwanenflugel (1996, p. 212) and van Merrienboer, Kester, Paas (2006, p. 343).

Scientific Process Skills

Carson (2004, p. 76-77) suggested that there is a significant difference between making science process skills ready for use by students by the teacher making an announcement and telling students to be prepared to figure out themselves which skills should be used under which conditions. This difference can be attributed to the effect of depth on learning (Novak & Gowin, 1984, p. 56-58). A learning environment unsupported by the component of depth might have negatively affected the success of the gifted students in the control group.

Complexity involves a simultaneous process of finding relations across components, i.e., parts or elements of knowledge that seemed unrelated before (Clark, 2008; Egan, 2010; Jensen & Nickelsen, 2008; Salmon, 1998; VanTassel-Baska & Stambaugh, 2006). It follows that, unless the construct of complexity is included in a learning environment, there is a possibility that skills are taught without focusing on the relations among them. As a consequence of giving less emphasis to such relations in the general science curriculum, it might be concluded that the gifted students in the control group did not succeed as much as the gifted students in the treatment group in terms of scientific process skills.

Attitude toward Science

Dodds' (2010) research findings established an explanation for why depth and complexity can positively affect the attitude toward science of students in the treatment group. Based on this research, it was hypothesized that there would not be a statistically significant difference in this study between the pre and post attitude scores of the control group in favor of the post test. The result obtained from the control group was contrary to the hypothesis of this study ($z=-2.53$, $p<0.05$). To develop an explanation for this discrepancy, the attitude scores of the control group were reviewed. It was found that 5 of 9 participants in the control group received the highest possible score (+20).

This unusual score distribution might have stemmed from a variable that could not be controlled. Prior to implementation of the research study, the students were divided into two groups, and the two classes were housed in the same building of the project school. Although their classrooms were located on different floors of the building, the students in the control group interacted with those in the treatment group during break times. The students in the control group recognized that the activities performed by the treatment group differed from theirs. Thereupon, some of the students in the control group wanted to transfer to the treatment group, but their requests were denied.

Rejection of these students in the control group may have created feelings of frustration over time. Assuming that these students wanted to express a reaction to the deprivation of favorable opportunities, they may have intentionally responded extremely happier than the way they normally feel (in an opposite way) when taking the attitude post test. As a result, the study does not provide adequate information to develop the conclusion that the treatment was either effective or ineffective at improving the attitude of these gifted students toward science education.

The explanation above calls into question how the interaction effect did not spread to the participants' performances on the academic achievement test and scientific process skills test. The answer mostly lies in the dissimilarity between scales and tests in terms of their measuring approaches. In the attitude scale, students were asked to express their feelings towards science education by letting them select an answer from the choices. In comparison with the scale, the tests used in this study had only one correct answer among the choices, and the students needed to solve questions accurately to succeed. The motivation to perform well while solving questions on the academic achievement and scientific process skills tests might have disappeared when the attitude scale was administered. This factor, the loss of achievement motivation, might have worked as a stimulant for the students in the control group to exhibit their reactions to being treated differently on the attitude scale.

Limitations and Recommendations

This research study demonstrates the importance of conceptualizing depth and complexity and developing ways to put these constructs into practice in the education of gifted students. The findings indicate the significance of depth and complexity in the educational needs of gifted students. Nevertheless, there was only one primary school for gifted students in the country, and the small number of gifted students in this school may have limited the ability to create different groups. Consequently, this case resulted in methodological limitations such as the groups could not be kept socially distant and therefore interacted with one another during the study. In addition, students are divided into two classes, the classes had to be placed at the same time in order not to conflict schedule.

From the time this project school founded at 2002, the place became a research field for master and doctorate students in Istanbul. That is to say, 5th grade students have familiarity of research activities for five years. So the possibility that statistically significant results can be explained by the "Hawthorne effect" which usually a limitation raised by the authors of experimental studies, could be assumed to be low.

Greater numbers of gifted students need to be studied to generalize these findings to the gifted population. In addition, the study was performed using only one unit in science education. The study lacks sufficient foundation to generalize its findings to other topics in science education or other academic subjects. For future research, multiple control-only and treatment-only schools might be studied, or gifted students who are diverse along lines of gender, socio-economic status, language, and ethnicity might be evaluated.

This research study was performed within a framework of enrichment in accordance with the national education programs. Notwithstanding the country's political consideration, another line of thought related to the education of the gifted leads to this potential research question: When an approach of acceleration is integrated with the approach of enrichment on the basis of depth and complexity, what is the effect on the learning by gifted students?

References

Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., Raths, J., & Wittrock, M. C. (2001). *A taxonomy for learning, teaching and assessing: a revision of Bloom's taxonomy of educational objectives*. New York: Longman.

Assouline, S. G., Blando C. A., Croft L. J., Baldus C. M., & Colangelo, N. (2009). Promoting excellence: Acceleration through enrichment. In J. S. Renzulli, E. J. Gubbins, K. S. McMillen, R. D. Erkert & C.A. Little (Eds.), *Systems and models for developing the gifted and talented* (2nd, pp. 1-17). Mansfield Center, CT: Creative Learning Press.

Attewell, P. (1992). Technology diffusion and organizational learning: The case of business computing. *Organization Science, 3*(11), 1-19.

Betts, G. T. & Kercher J. J. (2009). The autonomous learner model for the gifted and talented. In J. S. Renzulli, E. J. Gubbins, K. S. McMillen, R. D. Erkert & C.A. Little (Eds.), *Systems and models for developing the gifted and talented* (2nd ed., pp. 49-105). Mansfiled Center, CT: Creative Learning Press.

Borg, W. J., Gall, J. P., Gall, M. D. (1993). *Applying Educational Research: A Practical Guide* (3rd ed.). White Plains, NY: Longman Publishing Group.

Burns, J. C., Okey, J. R., & Wise, K. C. (1985). Development of an integrated process skill test: TIPS II [Abstract]. *Journal of Research in Science Teaching, 22*(2), 169-177.

Carr, M., Alexander, J., & Schwanenflugel, P. (1996). Where gifted children do and do not excel on metacognitive tasks. *Roeper Review*, *18*(3), 212-217.

Carson (2004). A taxonomy of knowledge types for use in curriculum design. *Interchange, 35*(1), 59-79.

Clark, B. (2008). *Growing up gifted: Developing the potential of children at home and at school* (7th ed.). Upple Saddle River, NJ: Merrill Prentice Hall/Pearson.

Çakar, E. (2008). *5.sınıf fen ve teknoloji programının bilimsel süreç becerileri kazanımlarının gerçekleşme düzeylerinin belirlenmesi.* (Unpublished doctoral dissertation). University of Süleyman Demirel, Isparta.

Davaslıgil, Ü., & Zeana, M. (2004). Üstün zekalıların eğitim projesi. In A. Kulaksızoğlu, & Bilgili, A. E. (Eds.). *I. Türkiye üstün yetenekli çocuklar kongresi bildiriler kitabı*(pp. 85-101). İstanbul: Çocuk Vakfı Yayınları.

Dodds, K. M. (2010). *Effects of the prompts of depth and complexity on gifted and non-gifted students (Unpublished doctoral dissertation)*. University of Southern California, Los Angeles.

Edwards, A. L. (1960). *Statistical methods for behavioral sciences* (2nd ed.). New York, NY: Rinehart & Company, Inc.

Egan, K. (2010). *Learning in Depth: A Simple Innovation That Can Transform Schooling*. Chicago and London: The University of Chicago Press.

Folk, S. (2006). Understanding understanding: a review of the literature. In K. Leithwood, P. McAdie, N. Bascia, & A. Rodrigue (Eds.), *Teaching for deep understanding: what every educator should know* (pp. 26-31). Thousand Oaks, CA: Corwin Press.

Gallagher, J. J., & Gallagher, S. A. (1994). *Teaching the gifted child* (4th ed.). Boston, MA: Allyn and Bacon.

Gay, L. R., Mills, G. E., & Airasian, P. (2006). *Educational research: Competencies for analysis and applications(8th ed.)*. Upper Saddle River, NJ: Pearson Education, Inc.

Geban, Ö., Aşkar, P. & Özkan, İ. (1992). Effects of computer simulation and problem solving approaches on high school [Abstract]. *Journal of Educational Research, 86*(1), 5-10.

Grotzer, T. A. (2005). Transferring structural knowledge about the nature of causality to isomorphic and non-isomorphic topics. Paper presented at the *American Educational Research Association Conference*, Montreal, Canada. Retrieved from http://isites.harvard.edu/fs/docs/icb.topic1117424.files/GrotzerAERA05.pdf.

Hays, W. L. (1963). *Statistics*. New York, NY: Holt, Rinehart and Winston, Inc.

Haskell, R. E. (2001). *Transfer of learning: Cognition, instruction and reasoning*. San Diego, CA: Academic Press A Harcourt Science and Technology Company.

Jensen, E., & Nickelsen, L. (2008). *Deeper learning: 7 powerful strategies for in-depth and longer-lasting learning*. Thousand Oaks, CA: Corwin Press.

Jonassen, D. H., & Gabrowski, B. L. (1993). *Handbook of individual differences.* Hillsdale, NJ: L. Lawrence Earlbaum Associates, Inc.

Kaplan, S. N. (2009). The grid: A model to construct differentiated curriculum for the gifted. In J. S. Renzulli, E. J. Gubbins, K. S. McMillen, R. D. Erkert, & C. A. Little (Eds.), *Systems and models for developing the gifted and talented* (2nd ed., pp. 235-253). Mansfield Center, CT: Creative Learning Press.

Kogut, B., & Zander, U. (1992). Knowledge of the firm, combinative capabilities and the replication of technology. *Organization Science, 3*(3), 383-324.

Lehrer, K. (2001). *Theory of knowledge*. Chicago, IL: University of Chicago Press.

Levent, F. (2011). *Üstün yetenekli çocukların hakları*. İstanbul: Çocuk Vakfı Yayınları.

MoNE (Ministry of National Education). (2005). *İlköğretim fen ve teknoloji dersi (4. ve 5.* sınıflar) öğretim programı, Ankara: Government Printing Office.

Moon, S.M., Kollof, P., Robınson, A., Dixon, F. & Feldhusen, J. F. (2009). The purdue three-stage model. In J. S. Renzulli, E. J. Gubbins, K. S. McMillen, R. D. Erkert & C.A. Little (Eds.), *Systems and models for developing the gifted and talented* (2nd ed., pp.289-323). Mansfiled Center, CT: Creative Learning Press.

Nuhoğlu, H. (2008). İlköğretim fen ve teknoloji dersine yönelik bir tutum ölçeğinin geliştirilmesi. *İlköğretim Online, 7*(3), 627-639.

Novak, J. D. (1998). *Learning, creating and using knowledge: concept maps as facilitative tools in schools and corporations*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Novak, J. D., & Gowin, D. B. (1984). *Learning How to Lea*r. NY: Cambridge University Press.

Page, S. E. (2011). *Diversity and complexity*. Princeton, NJ: Princeton University Press.

Perkins, D., & Salomon, G. (1989).Are cognitive skills context-bound? *Educational Researcher, 18*(1), 16-25.

Pollock, E., Chandler, P., & Sweller, J. (2002). Assimilating Complex Information. *Learning Instruction, 12,* 61-86.

Reis, S. M., & Renzulli, J. S. (2009). The schoolwide enrichment model: A focus on student strengths and interests. In J. S. Renzulli, E. J. Gubbins, K. S. McMillen, R. D. Erkert & C.A. Little (Eds.), *Systems and models for developing the gifted and talented* (2nd ed., pp. 323-353). Mansfiled Center, CT: Creative Learning Press.

Resnick, M. (1996). Beyond the centralized mindset. *Journal of the Learning Sciences, 5*(1), 1-22.

Sak , U. (2011). Üstün yetenekliler eğitim programları modeli (ÜYEP) ve sosyal geçerliliği. *Eğitim ve Bilim, 36*(161), 213-229.

Salmon, W. C. (1998). *Causality and explanation*. NY: Oxford University Press.

Schiever, S. W., & Maker, C. J. (2003).New directions in enrichment and acceleration. In N. Colangelo, & G. Davis (Eds.), *Handbook of gifted education* (3rd ed., pp. 163-173). Boston: Pearson Education Inc.

Silverman, L. K. (1993). A developmental model for counseling the gifted. In L. K. Silverman (Ed.), *Counseling the gifted and talented* (pp. 51-79). Denver, CO: Love Publishing Company.

Stanley, J. C., & Benbow, C. P. (1983). SMPY's first decade: 10 years of posing problems and solving them. *The Journal of Special Education, 17*(1), 11-25.

Taylor, M. C. (2003). *The moment of complexity: Emerging network culture*. Chicago, IL: University of Chicago Press.

Tokotro, M., & Steels, L. (2004). *A learning zone of one's own: sharing representations and flow in collaborative learning environments*. Washington, DC: IOS Press.

Tomlinson, C. A. (2009). The parallel curriculum: A design to develop high potential and challenge high-ability learners. In J. S. Renzulli, E. J. Gubbins, K. S. McMillen, R. D. Erkert & C.A. Little (Eds.), *Systems and models for developing the gifted and talented,* (2nd ed., pp. 571-599). Mansfield Center, CT: Creative learning Press.

Tomlinson C. A., & Jarvıs, J. M. (2000). Differentiation: Making curriculum work for all students through responsive planning and instruction. In J. S. Renzulli, E.

J. Gubbins, K. S. McMillen, R. D. Erkert & C.A. Little (Eds.), *Systems and models for developing the gifted and talented* (2nd ed., pp. 599-629). Mansfield Center, CT: Creative Learning Press.

Tomlinson, C. A., Kaplan, S. N., Renzulli J. S., Purcell, J., Leppien, J., & Burns, D. (2001). *The parallel curriculum: A design to develop high potential and challenge high-ability learners*. Thousand Oaks, CA: Corwin Press.

Van Merrienboer, J. J. G., & Kirschner, P. A. (2007). *Ten steps to complex learning. Mahwah*. New Jersey: Lawrence Erlbaum Associates, Inc.

Van Merrienboer, J. J. G., Kester, & L., Paas, F. (2006). Teaching complex rather than simple tasks: Balancing intrinsic and germane load to enhance transfer of learning.*Applied Cognitive Psychology, 20*, 343-352.

Van Merrienboer,J. J. G., Kirschner, P. A., & Kester, L. (2003). Taking the load off a learner's mind: Instructional design for complex learning. *Educational Psychologist, 38*(1), 5-13.

Van Merrienboer, J. J. G., & Sweller , J. (2005). Cognitive load theory and complex learning: Recent developments and future directions. *Educational Psychology Review, 17*(2), 147-177.

VanTassel-Baska, J., & Stambaugh, T. (2006). *Comprehensive curriculum for gifted learners* (3rd ed.). Boston, MA: Pearson/Allyn and Bacon.

VanTassel-Baska, J., & Wood S. M. (2009). The integrated curriculum model. In S. Renzulli, E. J. Gubbins, K. S. McMillen, R. D. Erkert & C.A. Little (Eds.). *Systems and models for developing the gifted and talented* (2nd ed., pp. 659-693). Mansfield Center, CT: Creative Learning Press.