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The Investigation of the Effectiveness of Applying Group Investigation Method at Different Intervals in Teaching Science Courses*

Fen Bilimleri Dersinin Öğretiminde Grup Araştırması Yönteminin Farklı Zamanlarda Uygulanmasının Etkililiğinin İncelenmesi

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ABSTRACT: The aim of the study was investigation the effect of twice application the Group Investigation method at different intervals on improvement of the students' academic achievement and science process skills in teaching the science lesson. Method of the study was a quasi-experimental design. The study used Solomon Four-group Experimental Design in the first year, and an experimental design in the second year which was created by adding a new experimental group to involve three experimental and two control groups. It was applied the Group Investigation method in the experimental groups and current methods on the curriculum of the secondary school science curriculum of Ministry of National Education in the control groups. Data collection process were used qualitative interview, preliminary information, science process skills and academic achievement tests. Applying the Group Investigation method for two years proved positive contributions to students' academic achievement and science process skills in science lessons. The researchers believe that experimental model developed this stduy will be used in different research areas in long-term studies in the future, and these studies will also make a great contribution to the literature.

Keywords: group investigation method, science education, science process skills, Solomon experimental design.

ÖZ: Çalışmanın amacı, Fen bilimleri dersinin öğretimde Grup Araştırması yönteminin farklı zamanlarda uygulanmasının öğrencilerin akademik başarılarını ve becerilerini geliştirmede etkisini incelemektir. Araştırmanın yöntemi, ön test- son test kontrol gruplu yarı deneysel desendir. Araştırmada ilk yıl Solomon Dört Gruplu Deneysel Deseni, ikinci yıl ilave bir deney grubu eklenerek üç deney ve iki kontrol gruplu yeni bir deneysel desen kullanılmıştır. Deney grubunda Grup Araştırması yöntemi, kontrol grubunda Milli Eğitim Bakanlığı fen bilimleri dersi öğretim programına ait mevcut yöntem uygulanmıştır. Veri toplama süreçleri ve araçları olarak yarı yapılandırılmış görüşmeler yapılmış; ön bilgi, bilimsel süreç becerileri ve akademik başarı testleri kullanılmıştır. Çalışmada Grup Araştırması yöntemini iki yıl boyunca uygulamanın fen derslerinde öğrencilerin akademik başarı ve bilimsel süreç becerisine olumlu katkılar sağladığı ortaya çıkmıştır. Araştırma geliştirilen deneysel desenin gelecekte yapılacak uzun vadeli araştırmalarda farklı araştırma alanlarında kullanılabileceği ve bu çalışmaların da alanyazına büyük katkılar sağlayacağı düşünülmektedir.

Anahtar kelimeler: bilimsel süreç becerileri, fen eğitimi, grup araştırması yöntemi, Solomon deneysel deseni.

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In today's educational approach, researchers often prefer constructivist teaching theories considering that learning is a socially oriented process and that knowledge is formed in people’s mind (Schunk, 2011). Use science concepts and the relationships between them in a meaningful way, to share ideas critically through social interaction, to question and to construct a common meaning by using constructivist teaching theories is aimed in science teaching (Köseoğlu & Tümay, 2015; Mehalik, Doppelt, & Schuun, 2008). In addition, this process is aimed students to gain science process skills. Because, science process skills, which enable individuals to use knowledge are critical for improving the skills needed in the qualified humanprofile (Güler & Şahin, 2015). According to Çepni, Ayas, Johnson, and Turgut (1996), science process skills; are the basic skills that help students to learn topics, gain research methods and enable students to take responsibility, be active, and learn permanently. In some studies in our country, the secondary school students’ science process skills have shown low (Aydoğdu & Ergin, 2009; Sezek, Zorlu, & Zorlu, 2015; Sinan & Uşak, 2011; Zorlu, Zorlu, Sezek, & Akkuş, 2013). This is possible with students active participation in the teaching process. Cooperative learning that support the active participation of the students to learn is helpful to reach a common goal through mutual interaction of the students (Avcı, 2002).

For the first time, the cooperative learning process, which was put forward in order to increase social communication and academic success in the classes with high ethnic diversity, has been regarded as one of the major and most successful innovations in the history of education and has become a standard part of the educational process in today's education (Slavin, 1999). The Cooperative learning model help students to involve in a learning environment in order to reach mutual benefits and changing the nature of the class from the product/content-oriented process into a process-oriented teaching (Johnson, Johnson, & Holubec, 1994; Sharan, 2015). studies on cooperative learning model are not only on academic success (Bilgin & Karaduman, 2005; Ergin, 2007; Rabgay, 2018; Şimşek, Doymuş, & Bayrakçeken, 2006) but also on attitudes, social interactions (Ebrahim, 2012), science process skills (Bozdoğan, Taşdemir, & Demirbaş, 2006; Chatila & Al Husseiny, 2017), macro-micro level comprehension skills (Şimşek, 2007), laboratory work skills (Bıyıklı, 2015), contribution to scientific writing (Bahadır, 2011) and contribution to academic writing (Jalilifar, 2010; Okur-Akçay, & Doymuş, 2012).

One of the methods used in the Cooperative learning model is the Group Investigation (GI) method. The GI method places students into small groups to research pre-determined issues. These small student groups prepare a study plan a research on the subjects assigned to them, implement the plan and collect data, use the collected information to solve a multidimensional problem and synthesize the information, and present the results to their classmates (Bayrakçeken, Doymuş, & Doğan, 2013). The group members’ take advantage of the diversity of the other group members while planning how to research the subject together. Students gain critical experiences for their social, psychological, and mental improvement throughout the process (Sharan & Sharan, 1992). The teacher has a facilitator, guide, and collaborator role in the student’s questioning process (Hertz-Lazarowitz & Calderon, 1994). Therefore, important results are achieved in terms of improving positive mutual dependence and internal motivation for the teachers and the students (Damini, 2014). According to Mitchell, Montgomery, Holder, and Stuart (2008), through the GI method not only the lower or moderately successful students improve, but also higher achieving students increase their performance.

When the related literature on GI method were investigated, the applications generally provided a positive contribution to the students' academic achievement (Aksoy & Gürbüz, 2013; Mitchell, Montgomery, Holder & Stuart, 2008; Sangadji, 2016; Sancı & Kılıç, 2011; Şimşek, Doymuş & Karaçöp, 2008; Şimşek, Doymuş, Doğan, & Karaçöp, 2009; Tan, Sharan, & Lee, 2007; Zorlu, 2016). Additionally, there are studies that show positive effects on the student's learning process and learning outcomes (Astra, Wahyuni, & Nasbey, 2015: Hosseini, 2014), motivation and perceptions (Tan, Sharan, Lee, & Christine, 2007), attitudes toward the environment (Lazarowitz, Hertz-Lazarowitz, Khalil, & Ron, 2013), the teachers' attitudes toward the diversity of the individuals (Damini, 2014), understand the particulate structure of matter (Doymuş, Şimşek, & Karaçöp, 2009), and motivation (Tan, Sharan, & Lee, 2007) by applying GI method only once. There is no such study that was conducted to determine the effect of the GI method that applied twice. However, considering the level of education of primary and secondary school students, by applying the GI method once may not be possible to see the full effects of the model. This situation may be related to the factors such as the lack of sufficient time, lack of being able to deal with students one-on-one, and lack of the students' ability to fully adapt to the GI method. In addition, it is thought that the effectiveness of GI method cannot be fully revealed due to the students' inability to get used to the method and the applications are performed in certain time periods. Because, when a subject is tried to be taught to the students by a learning method that they are not familiar with, they may need to learn the subject and the learning method at the same time. This is considered a major obstacle in measuring the actual impact of the learning method. For this, the methods used in the learning-teaching process should be provided to the students to become fully familiar with the method. After the students to become fully familiar with the method, the students' improvement can be measured with an application of the learning method.

According to Iswardati (2016), GI method is one of the effective methods that a teacher can apply when its effects and characteristics are considered. The GI method is based on interpersonal dialogue and focuses on the effective and social aspects of learning. In GI method, students get prepared for the given subject and they are prepared to synthesis new knowledge (Bayrakçeken, Doymuş, & Doğan, 2013). The subjects can be learned by enabling students to reach to the synthesis stage. In this study, carried out in this context; GI method was preferred in order to encouraging students of different characteristics to cooperative in and outside the classroom to create a common product, to ensure the active participation of each student in the learning process, so that social, group and personal benefits can be created. In addition, this study will guide the future studies in terms of investigating how a learning method can be applied to the same group at different times and how to investigate the effects of improvement.

In recent years, when we look at the studies on the science course, the students had difficulties in learning in micro level subjects such as particle structure, heat, heat conduction, temperature, structure of matter (Bischoff, 2006; Çepni, Aydın, & Ayvacı, 2000; Er Nas, 2013; Jacobi, Martin, Mitchell, & Newell, 2004). It was observed that students had misconceptions about the "States of Matter and Heat" and "Structure and

Properties Particle of Matter" subjects in the science courses including these concepts and difficulties in learning these issues (Ayas & Özmen, 2002; Bischoff, 2006; Çepni, Aydın, & Ayvacı, 2000; Jacobi, Martin, Mitchell, & Newell, 2004; Lubben, Netshisaulu, & Campbell, 1999; Stephan, 1994). When the studies in related literature were investigated there are many studies revealing the effects on the cooperative learning model (Damini, 2014; Mitchell, Montgomery, Holder, & Stuart, 2008; Şimşek, 2007; Tan, Sharan, Lee, & Christine, 2007). In the GI method, there is a goal of gaining high-level cognitive skills and there are difficulties in achieving this goal (Bayrakçeken, Doymuş, & Doğan, 2013; Schunk, 2011).

Attention should be paid to the frequency and time dimension of the application of learning methods (Johnson & Christensen, 2004). Especially in studies where the effects of a learning method are investigated, there may be situations where participants take time to get used to the method and may have indirect or indirect effects on the results to be achieved. The effects of these conditions can be minimized by performing the same applications at different times with the same students. Because after the first application, students have an idea of the method and application process and know what needs to be done to achieve the goal. The changes that arise as a result of the second application serve the purpose of revealing the effects of the applied method. The researchers and teachers has become knowledgeable of the level and qualifications of the students according to the method of learning applied and can carry out the guidance in this direction. Therefore, the second application enabled more qualified findings to be obtained in revealing the effects of the learning method In this study, it has been aimed to investigate the effects of twice application the GA method at different intervals on improvement of the students' academic achievement and science process skills in teaching the "States of Matter and Heat" and "Structure and Properties Particle of Matter" subjects. The problem of research:

Are there any effects of applying the GI method at the different intervals on improvement of the students' academic achievement and science process skills in teaching the Science course?

1. Are there any effects of the GI method first application on the students' academic achievement and science process skills in teaching the "Structure and Properties Particle of Matter" unit?

2. Are there any effects of the GI method second application on improvement of the students' academic achievement and science process skills in teaching the "States of Matter and Heat" unit?

Method

In this study, a quasi-experimental pre-test- post-test control group design was used. In the study, a revised form of the Solomon Four-Group Experimental Design was used since it is the strongest model among the experimental designs that secure internal and external validity at the same time (Karasar, 2016).

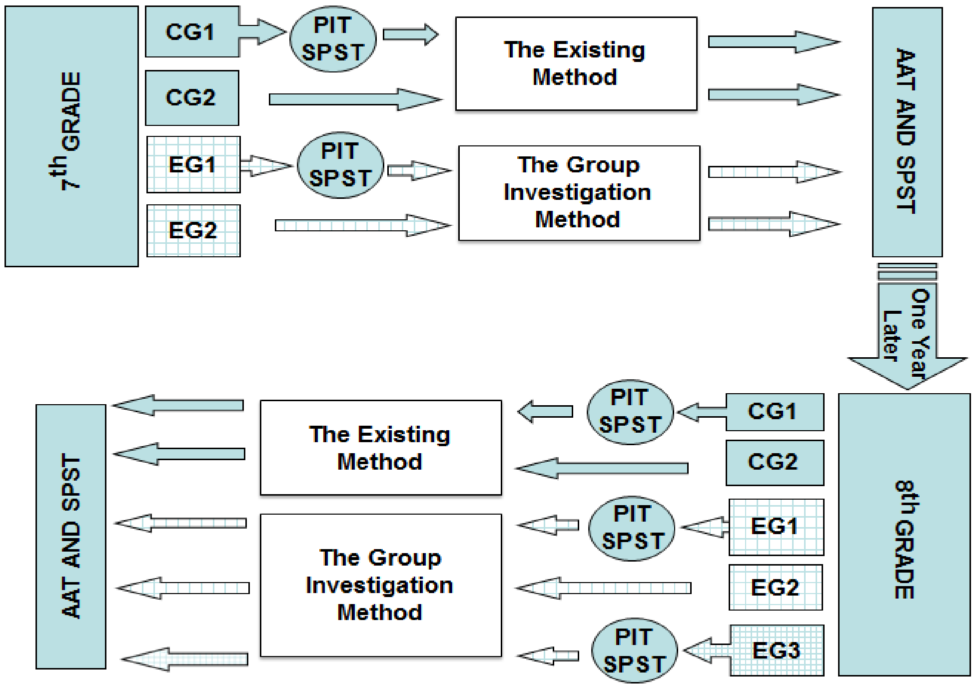
A control process is implemented in studies to minimize the effects on the dependent variable other than the independent variable effect (Gay, Mills, & Airasian, 2012). Control groups are included in experimental designs to make this process successful (Kala, 2014). Control groups are groups that do not affect the results of the pretested independent variable because they do not participate in the practice being performed. According to Creswell (2003, 2012), an assessment without a control group may cause the observed effects to look stronger or weaker than they really are. Therefore, studies conducted with control groups enable researchers to evaluate their implementation, detect the factors that affect the results and make comparisons. In experimental studies that are designed based on these points, typically two groups are included an experimental and a control group. However, these two-group comparisons may lead to biased assessments (Ertosun, Erdil, Deniz, & Alpkan, 2015). For this reason, researchers created Solomon Four-group Experimental Design, which tests four groups (Solomon, 1949). Solomon Four-group Experimental Design involves four groups formed by random (unbiased) assignment. Two of them are experimental groups, and two are control groups (Karasar, 2016). In scientific studies, the groups' knowledge about the practice in question is assessed by pretest before the implementation. Thus, researchers attempt to determine the current condition of the groups before the implementation. On the other hand, Sawilowsky, Kelley, Blair, and Markman (1994) believes that the pre-test processes are potentially weak, since the presence of a pre-test may have a considerable effect on the study result by stimulating the participants regarding the element to be assessed in the dependent variable (Holdnak, Clemons, & Bushardt, 1990; Solomon, 1949). In Solomon Four-group Experimental Design, only one experimental group and one control group are given a pretest, so researchers can observe the effect of the lack of a pre-test on the experimental and control groups' posttest scores and attempt to determine the effect of the implementation on both groups (Karasar, 2016; Neuman, 2014; Solomon, 1949).

Solomon Four-group Experimental Design makes it possible to make deeper comparisons and a wider range of interpretations by removing the effect between the implementation and the test since control groups are not subjected to the implementation, and one experimental and one control group do not take the pre-test (Babbie, 2013; Solomon & Lessac, 1968). Ayres, Hopf, and Will (2000) stressed the importance of considering other factors that may influence the participants in Solomon Four-group Experimental Design studies and focused on the possibility that repeated tests may have certain effects. This design also eliminates all of the internal validity issues mentioned by Campbell and Stanley (1980) (testing, regression, selection and interaction) (Weinrich, Seger, Curtsinger, Pumphrey, NeSmith, & Weinrich, 2007). Thus, the researcher believes that Solomon Four-group Experimental Design allows for deeper comparisons and assures studies' internal and external validity. A review of the studies conducted with Solomon Four-group Experimental Design showed that it requires at least three or four groups and is rarely used due to the fact that it takes a lot of time to create tests to analyze the inter-group correlations precisely (Braver & Braver, 1988; Harwell, 2011; Solomon & Lessac, 1968). Solomon Four-group Experimental Design eliminates these problems, allows for deeper comparisons and assures studies' internal and external validity. The relevant literature also shows that the methods in the cooperative learning model as well as the implementations that use Solomon Four-group Experimental Design are administered to the same sample only once (Andrews, Tressler, & Mintzes, 2008; Dirlikli, Aydın, & Akgün, 2016; Şimşek, Doymuş, & Şimşek, 2008).

Application of the Research Experimental Design

In this study, the research design was applied at different times for two years based on Group Investigation (GI) method. In GI method which is based on a person-to-person dialogue, students who divide into groups of five to six heterogeneous persons work in a manner that is responsible for the learning of each other in the determined academic subject. The resulting product is presented to the class as a whole and evaluated (Johnson, Johnson, & Holubec, 1994; Sharan & Sharan, 1992). The experimental design of the research is given in Figure 1.

Figure 1. Experimental Design of Research



In the first year, Solomon Four-group Experimental Design and the GI method are administered to the seventh grade students in the unit, Structure and Properties Particle of Matter. The implementation was conducted in two secondary schools under MEB with volunteer teachers because in the first year of the implementation four classes would participate while in the second year five classes would be needed. The four classes were determined by means of simple random sampling, two were identified as the experimental group (EG1 and EG2) and the remaining two were identified as control groups (CG1 and CG2). The pretest was administered to one experimental group (EG1) and one control group (CG1).

In the GI method, heterogeneous groups were divided into the Preliminary Information Test (PIT) in the EG1 while they were divided into according to their success in Science class in the EG2. The heterogeneous groups in the classes were divided into two parts identified as PART 1 and PART 2. The group members were seated close to each other to establish and facilitate face to face communication. The groups chose their leader and determined the name of their group. Each student in the groups was identified by a code (e.g. the students in group A could be A1, A2, A3, and A4). The students were informed that they were responsible for each other's learning. Each group made plans according to the objectives of the "The Structure and Properties of Matter" unit and shared in the tasks. They conducted their research on the unit inside and outside of the classroom. The numbers of groups which would make presentations was determined based on allocation of time. During a class period, one group presented while the other group watched and tried to correct any observed errors. Additionally, questions were collected from the other students in the class and asked to the presenting group. Throughout the process, the students were diligently observed by the researcher and feedback was provided. After the presentations, a classroom assessment was conducted. Seventh Grade-Academic Achievement Tests (SG-AAT) and Seventh Grade-Scientific Process Skills Tests (SG-SPST) were administered.

In the control groups, the courses were processed according to the current learning method. In the current learning method, the application is based on the curriculum of the secondary school science curriculum of MEB and is usually explained by the teacher of the course. After the instruction, the researcher made an effort to eliminate the students' deficiencies by doing evaluation exercises in the textbook together with the students. After the implementation, the post-test was administered to all four groups, which concluded the study's first year (Table 1).

Table 1

The First Year Application Process

Application	Hours of Lessons
Pre-test (Groups: EG1, KG1; Tests: PIT, SPST)	
Elements and Their Symbols	4
Atomic Structure	4
Compounds and Their Symbols	4
Electron Distribution and Chemical Characteristics	4
Chemical Bond	4
Mixtures	4
Post-test (Groups: EG1, EG2, KG1, KG2; Tests: AAT, SPST)	

In the second year, Solomon Four-group Experimental Design was revised with the purpose of precisely determining the effectiveness of the GI method practices. The researcher added another group (EG3) to the eighth graders to see the difference between the students that studied with the GI method twice and those that studied with it only for once. Finally, the researcher obtained a research design that involved two control groups and three experimental groups. In the second year, the implementation was held in the unit, States of Matter and Heat. The GI method was implemented to the experimental groups, while the control groups were taught using the current teaching method. In the second step, the GI method which had been administered in the experimental groups in the first year and the traditional learning method used in the control groups were repeated. The heterogeneous groups in EG3 were formed according to the Preliminary Information Test (PIT) scores (Table 2).

Table 2

The Second Year Application Process

Application	Hours of Lessons
Pre-test (Groups: EG1, EG3, CG1; Tests: PIT, SPST)	
Heat and Temperature	4
Heat Exchange and Change of Temperature	4
Heat Exchange and Change of State	4
Post-test (Groups: EG1, EG2, EG3, CG1, CG2; Tests: AAT, SPST)	

Participants

Students attending 7th and 8th grades in two public secondary schools composed the sample of the study. First year (First application), it was four classes in the 7th grades. The four classes were randomly selected as experimental and control groups. In total, 111 seventh graders participated in the first application. It was consist of 56 students (22 Female and 34 Male) the experimental groups and 55 students (23 Female and 33 Male). Second year (Second application), it was five classes in the 8th grades that the four classes from first year (first application). Of them, 84 were students from the first year, and 25 were from the experimental group added afterwards. In the second year of the implementation, 10 students from the experimental groups of the first year as well as 17 students from the control groups of the first year did not participate in the second year implementation since they changed either their schools or classes. In the second year, 109 students participated in the research. It was consisted of 71 students (31 Female and 40 Male) the experimental groups and 38 students (15 Female and 23 Male). Two science teachers (1 female, 1 male) participated in the study.

Data Collection Process

A detailed presentation was made before the data was collected. The data collection tools were introduced. The research is a scientific study and it is explained that any information of their own will not be used for other purposes was stated to the students. Attention was paid to collect data within the framework of ethical rules.

Quantitative data collection process and tools

Preliminary information tests (SG-PIT and EG-PIT). It was taken from the TUBITAK (Scientific and Technological Research Council of Turkey) project (Number of project: 110K252). The researcher also created tests to be informed about the preliminary knowledge levels of the seventh and eighth grade students in the science and technology course (SG-PIT and EG-PIT). The reliability levels of the tests (KR 20) were .63 for SG-PIT and .65 EG-PIT (Doymuş, 2012). Before the study, the researcher conducted a pilot study with a group that was not included in the implementation or the control groups to see whether the scales and tests used in the study suited the participants' levels. This study, the reliability levels of the tests (KR 20) were .67 for SG-PIT and .61 for EG-PIT.

Science process skills tests (SG-SPST and EG-SPST). The science process skills test used for the seventh grade students (SG-SPST) was the Science Process Evaluation Test. The original form of this test was created by Smith and Welliver (1990), and it was translated and adapted to Turkish by Başdağ (2006). This test evaluates 13 science process skills: observation, classification, making inferences, estimation, assessment, data registration, building correlations between numbers and space, functional description, establishing hypotheses, making experiments, determining variables, interpreting data and creating models. The test has 40 questions. Başdağ (2006) found its reliability to be .81. Before the study, the researcher conducted a pilot study with a group that was not included in the implementation or the control groups to see whether the scales and tests used in the study suited the participants' levels. This study was found its reliability to be .78.

The science process skills test used for the eighth grade students (SG-SPST) was created by Okey, Wise, and Burns (1982) and adapted for Turkish use by Geban, Aşkar, and Özkan (1992). The alpha reliability coefficient of the test was .85. The subsections of the test were the ability to recognize the variables in problems (12 questions), establishing and describing hypotheses (8 questions), the ability to make operational explanations (6 questions), designing the steps required for solving problems (3 questions), and drawing and interpreting charts (7 questions). Prior to the study, the researcher conducted a pilot study with a group that was not included in the implementation or the control groups to see whether the scales and tests used in the study suited the participants' levels. This study was found its reliability to be .86.

Academic achievement tests (SG-AAT and EG-AAT). It was taken from the TUBITAK (Scientific and Technological Research Council of Turkey) project (Number of project: 110K252). These tests consisted of 30 multiple-choice questions about the unit, The Structure and Properties Particle of Matter, on the seventh grade academic achievement test (SG-AAT), and 25 multiple-choice questions about the unit, States of Matter and Heat, on the eighth grade academic achievement test. According to KR-20, the reliability coefficient of the tests were .75 (seventh grade) and .69 (eighth grade) (Doymuş, 2012). Prior to the study, the researcher conducted a pilot study with a group that was not included in the implementation or the control groups to see whether the scales and tests used in the study suited the participants' levels. This study, the reliability levels of the tests (KR 20) were .77 for SG-AAT and .65 fot EG-AAT.

Qualitative data collection process and tools

A qualitative interview was used to collect data when using the guidance-interview approach. Interviews were conducted at the end of the application in order to reveal feelings, motivations, beliefs, and reflections regarding the application (Kutluca, 2014). The interview protocol consisted of three open-ended questions—developed by the researcher—on the students’ characteristics it improved, the difficulties in the application, and the suggestions made. The interview sessions were held face-to-face with the two participating teachers for 30–35-minute periods. All interviews were recorded with the permission of the teachers and were transcribed afterwards.

Data Analysis

Analysis of quantitative data

The Shapiro-Wilk test was conducted to determine whether the GI method tests were parametric, and the test results were given in Table 3.

Table 3

Shapiro-Wilk Analysis Results of the Data Obtained for the Eighth Grades of the Group Investigation (GI) Method

Tests	Shapiro-Wilk			Tests	Shapiro-Wilk		
	Statistic	*Sd*	*p*		Statistic	*Sd*	*p*
SG-PIT	.973	55	.262	EG-PIT	.956	78	.008
SG-SPST$_{Pretest}$	.976	55	.002	EG-SPST$_{Pretest}$	.958	78	.011
SG-AAT	.978	111	.046	EG-AAT	.960	109	.008
SG-SPST$_{Posttest}$	.976	111	.041	EG-SPST$_{Posttest}$	.967	109	.009

Table 3 concluded that the Preliminary Information Test for the Seventh Grade was parametric, while the other tests were non-parametric. The researcher did the relevant analyses based on these results. The quantitative data of the study were analyzed using SPSS software. The SG-PIT was used the independent t-test for analysis. The other tests were used Mann-Whitney U and Kruskal-Wallis tests for analysis.

Analysis of qualitative data

A content analysis was used to analyze the teachers' perspectives. Sub-themes were formed according to the teachers' answers to the three questions posed; namely, positive aspects, negative aspects, and suggestions regarding main theme. Teachers' perspectives were presented in tables according to these sub-themes.

Practices for Validity and Reliability of the Research

In the first year implementation, the researcher used Solomon Experimental Design to ensure the internal and external validity of the study. In the second year implementation, the researcher revised the Solomon Experimental Design and added another experimental group, which was administered an implementation that served the objective of the study. The researcher also attempted to finalize the new experimental design by consulting two faculty members who specialize in this field of study. Prior to the study, the researcher conducted a pilot study with a group that was not included in the implementation or the control groups to see whether the scales and tests used in the study suited the participants' levels. Student groups that were heterogeneous in terms of academic achievement were chosen for the research. The standard deviation and range values of the data collected in the pretest confirm this (Table 4 and 6). Before the implementation, the researcher informed the students and teachers participating in the research about the implementation, which involved the collaboration of the researchers and the sciences' teacher. The course teacher was asked to behave objectively and interfere in the process when necessary. The researchers also paid attention to the physical suitability of the classroom. It was ensured that the students responded to the tests and scales individually and that all groups had the same amount of time to do them.

Results

In order to administered to see the students' preliminary knowledge levels in the science course, the SG-PIT independent-t test and the $\text{SG-SPST}_{\text{Pretest}}$ were analyzed with Mann-Whitney U test and given in Table 4.

Table 4

Descriptive and Estimated Statistical Results of SG-PIT and SG-SPST (Pre-test) of Seventh Grades Applied for the First Time by GI method

Tests	Groups	*n*	$\bar{X}$	*Sd*	*t*	*p*
SG-PIT	EG1	29	46.48	11.68	1.097	.277
	CG1	26	43.08	11.27		
$\text{SG-SPST}_{\text{Pretest}}$	EG1	29	26.31	7.087	341.000	.543
	CG1	26	25.96	5.188		

Table 4 shows that there was no significant difference between the groups pre-test scores for the seventh and eighth grades (SG-PIT: t=1.097; p=.277. $\text{SG-SPST}_{\text{Pretest}}$: U=341.000; p=.543). The students in experimental and control groups were equal to each other in terms of their preliminary knowledge and science process skills in the sciences course.

When the first year implementation was completed, applied to students SG-AAT and $\text{SG-SPST}_{\text{Posttest}}$ were analyzed with Kruskal-Wallis test and given in Table 5.

Table 5

Descriptive and Estimated Statistical Results of SG-AAT and SG-SPST (Post-test) of the Sixth Grades for the First Time of GI Method

Tests	Groups	*n*	$\bar{X}$	*Sd*	X^2	*p*	η^2	Difference*
SG-AAT	EG1	29	66.92	17.61	14.48	.002	.13	EG1-CG1, CG2
	EG2	27	63.04	17.62				EG2-CG1, CG2
	CG1	26	50.62	18.69				
	CG2	29	51.03	18.75				
$\text{SG-SPST}_{\text{Posttest}}$	EG1	29	29.31	3.96	14.909	.002	.14	EG1-CG1,CG2
	EG2	27	29.00	5.64				EG2-CG1,CG2
	CG1	26	25.96	5.19				
	CG2	29	24.55	5.91				

*Statistically significant groups are indicated.

Table 5 shows that the mean scores of the students in EG1 and EG2 on the Seventh Grade Academic Achievement Test were higher than the mean scores of the students in CG1 and CG2. The researchers used the Kruskal-Wallis test to see whether that difference was statistically significant. The results of the analyses indicated that there was a statistically significant difference between the arithmetic means of students' academic achievement test scores [$X^2_{(3)}$=14.48; p=.002]. The first year model's effect size (eta-squared-η^2) showed that it explained 13% of the difference between the academic achievement levels of the experimental and control groups. The researchers used the Mann-Whitney U test to examine this difference. There was no significant difference between EG1 and CG1, EG2 and CG2, and CG1 and CG2. The study concluded that the GI method made positive contributions to students' achievement.

The Table 5 shows that the post-test scores of the students in EG1 and EG2 were higher than the mean scores of the students in CG1 and CG2. The researchers used the Kruskal-Wallis test to see whether that difference was statistically significant. The results of the analyses indicated that there was a statistically significant difference between the arithmetic means of the students' post-test scores [$X^2_{(3)}$=14.909; p=.002]. The first year model's effect size (eta-squared-η^2) showed that it explained 14% of the difference between the science process skills levels of the experimental and control groups. The researchers used the Mann-Whitney U test in double groups to see the groups that had differences between them. There were significant differences between EG1 and CG1, EG2 and CG2, and CG1 and CG2 (p<.05). The study concluded that the GI method made positive contributions to the students' science process skills. The study also used the Kruskal-Wallis test for each skill to see the science process skills that correlated with the groups. The results indicated that there were significant differences between groups regarding “Observation”, “Estimation”, “Assessment”, “Building Correlations Between Numbers and Space”, “Establishing Hypotheses and Doing Experiments” [Observation: $X^2_{(3)}$=18.037; p=.000. Estimation: $X^2_{(3)}$=8.354; p=.039. Assessment: $X^2_{(3)}$=9.170; p=.027. Building Correlations Between Numbers and Space: $X^2_{(3)}$=16.503; p=.001. Establishing Hypotheses: $X^2_{(3)}$=6.731; p=.001. Doing Experiments: $X^2_{(3)}$=10.172; p=.017]. The researchers used the Mann-Whitney U test in double groups to see the groups that differed significantly in science skill. The results showed that there were significant differences between EG1 and/or EG2, and CG1 and/or CG2 in the skills of observation, estimation, assessment, building correlations between numbers and space, establishing hypotheses and doing experiments (p<.05). In these skills, the GI method made positive contributions to the students' skills.

In the second year of the study, in order to determine the students' preliminary knowledge and the level of science process skills in sciences course, applied EG-PIT and EG-$SPST_{Pretest}$ were analyzed with Kruskal-Wallis test and given in Table 6.

Table 6

Descriptive and Estimated Statistical Results of EG-PIT and EG-SPST (Pre-test) of Eighth Grades for the Second Time of GI Method

Tests	Groups	*n*	$\bar{X}$	*Sd*	X^2	*p*
EG-PIT	DG1	31	52.74	15.05	2.432	.296
	DG3	27	49.26	19.05		
	KG1	21	56.43	14.76		
EG-SPST$_{Pretest}$	DG1	30	13.43	5.022	2.982	.225
	DG3	27	12.22	3.866		
	KG1	21	14.43	4.342		

It was observed that the students in the experimental group and the control group had similar levels of preliminary knowledge in sciences and science process skills in Table 6 [EG-PIT: $X^2_{(2)}$=1.656; *p*=.296. EG-SPST$_{Pretest}$: $X^2_{(2)}$=2.982; *p*=.225).

When the second year practices were completed, applied to students EG-AAT and EG-SPST$_{Posttest}$ were analyzed with Kruskal-Wallis test and given in Table 7.

Table 7

Descriptive and Estimated Statistical Results of EG-AAT and EG-SPST (Post-test) of Eighth Grades for the Second Time of GI Method

Tests	Groups	*n*	$\bar{X}$	*Sd*	X^2	*p*	η^2	Difference*
EG-AAT	EG1	26	59.04	14.97	14.980	.005	.154	EG1-CG1, CG2
	EG2	20	61.00	15.27				EG2-CG1, CG2
	EG3	25	54.80	12.46				EG3-CG1
	CG1	20	45.00	14.42				
	CG2	18	48.00	15.06				
EG-SPST$_{Posttest}$	EG1	26	17.15	4.09	11.161	.025	.107	EG1-CG2
	EG2	20	16.95	3.73				EG2-CG2
	EG3	25	15.16	3.59				
	CG1	20	14.75	4.25				
	CG2	18	13.72	3.20				

* Statistically significant groups are indicated.

The Table 7 shows that the students in EG1, EG2, and EG3 had higher mean scores on the academic achievement test that the students in CG1 and CG2. The study used the Kruskal-Wallis test to determine whether this difference was statistically significant. The results of the test indicated that there was a significant difference between students' academic achievement means scores [$X^2_{(4)}$=31.15; *p*=.005]. The second year model's effect size (eta-squared-η^2) showed that it explained 15.4% of the difference between the academic achievement levels of the experimental and control groups. The Mann-Whitney U test was performed in double groups to examine this difference. There were statistically significant differences between EG1 *and* CG1 and CG2, and CG1 and CG2 *and* EG3 and CG1 (p<.05). The results of the Solomon Research Design showed that the experimental groups were equal to each other and the control groups were also equal statistically. The internal and external validity of the study was also ensured since the experimental groups had higher achievement than the control groups. These outcomes prove that the GI method made positive contributions to the students' achievement.

The groups' scores on the posttest (Science Process Skills for Eighth Grade) ranked EG1, EG2, EG3, CG1 and CG2. The researchers used the Kruskal-Wallis test to determine whether the score differences between the groups were statistically significant. The results showed that there was a significant difference between the mean rank of the students' scores on the posttest [$X^2_{(4)}$=11.161; p=.025]. The second year model's effect size (eta-squared-η^2) showed that it explained 10.7% of the difference between the science process skills of the two groups. The study also used the Mann-Whitney U test to see the groups that differed. There was a statistically significant difference between EG1 and CG2, and EG2 and CG2. The researchers used the Kruskal-Wallis test for each of the science process skills to see the groups' significant differences. They found that the groups had statistically significant differences in the skill of “Determining the Variables” [$X^2_{(4)}$=10.633; p<.05]. The Mann-Whitney U test was performed in double groups to determine the groups that had significant differences between them. There were statistically significant differences between EG1 and KG2, and EG2 and KG1 and KG2 (p<.05), which implies that using the GI method for two years made positive contributions to the students' achievement.

The two science teachers' views about the application who participated in the application were taken. The views are given in three themes: positive, difficulties and recommendations.

Table 8

Teachers' Positive Perspectives on the Application

Teachers' Perspectives	İlhan	Bengisu
Come to courses preparedly	✓	✓
Active participation	✓	✓
Increase achievement	✓	✓
Governing/managing skills attainment	✓	✓
Performed more comfortable courses (without time constraints)	✓	✓
Providing to see themselves valuable	✓	✓
Improve their self-confidence	✓	✓
Providing to be guide of teacher	✓	
Providing sharing	✓	

As seen in Table 8, teachers stated that applications of group investigation provided students to help them come to courses preparedly, active participation, improve their self-confidence, performed courses easier, and increase their achievement, governing/managing skills attainment and self-esteem. Teachers highlighted that the course was performed more comfortably, that students learned the subject better without teachers, that the course was taught more efficiently, and that students were improved in terms of both knowledge and skills since students were familiarized with the process due to the application being carried out twice.

> "The application was provided students so that they could more actively participate in the course and increase their achievement. It even facilitated participation from those students who were not interested in the course and increased their achievement. (…) The group heads encouraged their peers, a situation requiring them to put in extra effort to increase their group mates' achievement. In conclusion, the achievement of the low-achieving students was increased per this application. During the process, each group designed materials independently of one another, the groups then contributed to each other through the materials designed at the end of the process. (…) Students experienced some difficulties at certain points, though managed to overcome them, either through their own research or with the teacher's guidance. (…) Students saw themselves as more valuable because they were given the chance to make a presentation and express their thoughts; this increased their self-confidence. I caught some indicators such as 'I can do it now' in the behavior of students who never participated in the course. (…) Students' high achievement in the application that has been carried out twice provided their learning be permanent. Almost all the students gave correct answers to the questions for the unit in the written examination of the 7th-grade in which in particular, the application was carried out twice."(Teacher İlhan)

> "I noticed that students participated in the course by holding a file and preparing for the topics through group discussions because they were going to teach the course. (…) I observed that students participated in the course more, that the students who had previously had a low-participation history in the course also tried to participate (…), and that these students learned the topic without the help of the teacher; however, some of these students missed certain key points. I observed that the students had control over the topic in a general sense. (…) I also observed that students comprehended the topic when the teacher provided guidance by addressing these missing points (…), and that the application assigned students responsibility. It also made it easier for students to know which part of the topic was more important. (…) This model provided students to comprehend the course. (…) I observed that the group heads acquired governing and directing skills at the end of the application due to their increased responsibility during the process itself. (…) Students already had the prerequisites since the model was carried out for the second time. They knew what to do on their own without needing any help or further in-depth information about the process." (Teacher Bengisu)

Table 9

Teachers' Perspectives about the Difficulties Encountered During the Application

Teachers' Perspectives	İlhan	Bengisu
Familiarizing students with the method applied	✓	
Destruction of Old Habits	✓	
Course preparation process	✓	
Classroom management		✓
The crowd of classrooms for the group study		✓

As seen in Table 9, teachers had difficulties when familiarizing students with the method applied, destructing the habits related to teacher-centered educational understanding, the course preparation process, and with classroom management when dealing with crowded classes. Teachers indicated that—since the students did not know how to prepare for the lesson or how to manage the process—they encountered difficulties with those classes wherein the application was being carried out for the first time, and that they experienced difficulties regarding classroom management due to the number of students during the group study and the inappropriate physical design of the classrooms.

> "There were some deficiencies in the 7th-grade wherein the application was being carried out for the first time. The students on the board occasionally taught the topic by reading from the text or else could not answer the questions. Another deficiency I noticed is that the topic was assigned to the group members equally… I think that it would be a better strategy to assign low-achieving students a relatively lower-responsibility task instead of assigning responsibility equally because this can cause problems for those groups wherein a low-achieving student is responsible for a difficult topic. Such a case was encountered in one of the groups of 8th-graders, wherein the model had been applied to for two years; some troubles were encountered in this group since the student developed a sense of hate towards both the course and the application itself." (Teacher İlhan)

> "I think that the classes were too crowded for a group study. Therefore, we experienced some trouble. I observed that in such applications, certain difficulties were encountered to ensure classroom management in crowded classrooms." (Teacher Bengisu)

Table 10

Teachers' Suggestions for the Application

Teachers' Suggestions	İlhan	Bengisu
Should be in all educational levels	✓	✓
Should be applied different methods in primary school	✓	✓
Should attainment the prerequisites of the method when application process	✓	✓
Should comprise fewer students of the groups		✓

As seen in Table 10, teachers suggested to apply such applications by using different methods throughout all educational levels, particularly starting from primary education and to provide the prerequisites as in this application. Teachers also indicated that groups should be comprised of fewer students if such applications are to be performed more comfortably and efficiently in the future.

> "The applied model should be understood very well. As this application suggested, such studies should not be limited to a single course. I think that the application can be carried out successfully alongside with other courses… I believe that students can be more successful by applying this model from 5th-grade to 8th-grade of middle school, to even into university education. In fact, the greatest problem is that students attend courses without undertaking the necessary research regarding the relevant topic. One way to eliminate this problem would be to improve students' research skills by using different methods and shifting their understanding of teacher-centered education."(Teacher İlhan)

> "Students had the prerequisites and awareness regarding the topic since the application had been carried out twice; they were able to run the process on their own without being told what to do. These applications require consideration. (…) If such applications are occasionally carried out regarding all the appropriate topics within those grades starting from primary education, future applications will be designed more efficiently. (…) I think that these applications would be better performed in groups consisting of several students in non-crowded groups."(Teacher Bengisu)

Discussion, Conclusion, and Implications

A review of the findings obtained from the pre-tests (the Preliminary Knowledge and Science Process Skills Tests for Seventh Grade) for Solomon Research Design and GI method in the first year showed that there were no statistically significant differences between the groups (Table 4). The data obtained from the Academic Achievement Test for Seventh Grade and Science Process Skills Test for Seventh Grade in the GI method practices showed that there was a significant difference to the advantage of the experimental groups (EG1 and EG2) (Table 5). In other words, the GI method affected students' academic achievement positively in the unit, The Structure and Properties Particle of Matter. The results obtained are in line with the results of the literature on the GI method (Astra, Wahyuni, & Nasbey, 2015; Mitchell, Montgomery, Holder, & Stuart, 2008; Sancı & Kılıç, 2011; Şimşek, Doymuş, & Karaçöp, 2008; Şimşek, Doymuş, Doğan, & Karaçöp, 2009; Tan, Sharan, & Lee, 2007; Zorlu, 2016; Zorlu & Sezek, 2016). There were significant differences to the advantage of the experimental groups in the science process skills of observation, assessment, building correlations between numbers and space, establishing hypotheses, and doing experiments. Examining the research subject comprehensively is one of the features of the GI method. While trying to solve problems, students establish their own knowledge based on what they have learned about the subject (Bayrakçeken, Doymuş, & Doğan, 2013; Efe, Hevedanlı, Ketani, Çakmak, & Efe, 2008). In this regard, there is a relation between this aspect of the GI method and the science process skills that students acquire.

The pre-tests of experimental designs can cause negative effects on the results by stimulation, causing psychological sensitivity and creating a competitive environment (Ayres, Hopf, & Will, 2000; Babbie, 2013; Holdnak, Clemons, & Bushardt, 1990; Sawilowsky, Kelley, Blair, & Markman, 1994; Solomon, 1949). The post-tests found no significant difference between the experimental or control groups that did or did not take the pretest (Table 5 and Table 7). Based on these findings, the researchers concluded that the pretest did not have any effect on the results of this study.

Creswell (2003) believed that the lack of additional control groups in experimental designs made methods look either stronger or weaker. Büyüköztürk (2014) also noted that the behaviors displayed by subjects may differ from their natural behaviors since they are aware of being included in an experimental study, which reduces the generalizability of research results. On the other hand, there are many studies claiming that an increase in the number and period of the implementations made with the same subjects will also improve the causal relation and make the implementation results more generalizable (Creswell, 2003; McMillian, 2008; Solomon, 1949). Solomon designed the Four-group Experimental Design to see whether subjects are affected by this, and rectified it by observing the equivalence of results from experimental and control groups that do or do not take the pretest. This improved the internal and external validity of scientific studies (Christensen, Johnson, & Turner, 2015; Weinrich et. al., 2007). This study added an extra experimental group to the eighth grade groups, which participated the implementation once, with the aim of observing students' improvement after two years of GI method implementation.

✓ This both increased the number of participants in the sample and made it possible to examine the new aspects that students gained through the GI method (academic achievement and science process skills) by comparing the study results with the results of this group.

✓ It also provided results that were more suitable for generalization since it improved the correlation between the dependent and independent variables (Table 7).

✓ Finally, in the studies conducted by Campbell and Stanley (1980), Solomon Four-group Experimental Design helped them better meet the interval validity criteria of maturation, testing, regression, selection and interaction (Weinrich et. al., 2007).

The findings from the pre-tests (Preliminary Knowledge Test for Seventh Grade and Science Process Skills Test for Seventh Grade) in the GI method practices performed in the sciences course in the second year of study proved that there were no statistically significant differences between the groups (Table 6). The results of the Academic Achievement Test for Seventh Grade in the GI method practices showed that there was a statistically significant difference between the groups to the advantage of the experimental groups (Table 7). Furthermore, it was determined that the experimental groups that participated in the practice for twice had a higher academic achievement than the experimental groups that were participants for only once. According to this result, it can be said that applying twice at the different times the GI method improves the students' academic achievement in the "States of Matter and Heat" unit. When the results of EG-SPST were investigated, it was determined that the GI method was partly effective in improving science process skills. The experimental design in the second implementation explained 10.7% of the difference in the EG-SPST when the effect-size of the GI method was investigated. This has a direct correlation with the research process of GI method (Bayrakçeken, Doymuş, & Doğan, 2013; Dikel, 2012; Doymuş, 2012). The GI method also enables students to perform activities with which they establish causal relations and determine their variables. In the skills of "Determining Variables", the significant difference was to the advantage of the experimental groups that participated in the implementation for two years. However, there was no statistically significant difference between the control group and the group that participated the implementation for only one year. Applying the GI method for two years helped improve students' skill in "Determining Variables". In the curriculum, the skill of "Determining Variables" in eighth grade sciences involves approximately thirty acquisitions and the largest number of acquisitions in the "Matter and Heat" unit as well (MEB, 2013).

It is possible to explain the results obtained from the study in two different situations. The first is to apply the learning method twice at the different intervals and the second is useful in GI method. It can be said that students' academic success and science process skills are improved by applying the learning method twice at different times because of ensuring students become accustomed to the method, being aware of what they need to do in the process. Knowing the applied learning method allows the students to learn the subjects better by being planned and active in the lessons (Kaufman, 2014; Schwarz, de Groot, Mavrikis, & Dragon, 2015). In this study, since the students learned GI method in the first application, they were able to apply the GI method fully in the second application. Students come together with group friends outside the classroom to work more planned lessons, focusing on the learning of students in the whole group while learning the subject, and being active properties can be said to develop by applying twice at the different intervals the GI method. In the GI method, out-of-class group work and synthesis learning subjects are involved (Bayrakçeken, Doymuş, & Doğan, 2013). It can be said that students' academic achievement and scientific process skills improve because of the properties which out-of-class group work and synthesis learning subjects of GI method.

According to the findings obtained from EG-SPST no statistically significant difference existed between the experimental and control groups in the following skills; “Hypothesizing and Defining”, “Making Operational Explanations”, “Designing the Required Investigations for the Solution of the Problem”, and “Drawing a Chart and Interpretation”. Therefore, the implementation of GI method to teach the “States of Matter and Temperature” unit was not effective in teaching these four scientific process skills. Scientific process skills can be taught and improved by means of experiments and activities (Hofstein, Navon, Kipnis, & Naaman, 2005). Different teaching methods and techniques may be used along with GI including experiments and activities. In the study by Zorlu (2016) the GI method was implemented along with the modelling-based teaching method in science class and benefits were observed in the students’ acquisition of “Hypothesizing (Guessing)”, “Experimenting and Designing Experiments”, “Establishing Number-Space Relationship”, and “Modelling” skills. Administering the activities of the modelling-based teaching method to students may enable them to understand and conduct scientific experiments to form mental models (Halloun, 2007, 2011; Ünal-Çoban, 2009; Zorlu & Sezek, 2019).

Teachers’ perspectives also supported the fact that, by applying it twice, the Group Investigation (GI) method contributed to students’ skills regarding academic achievement and scientific processes. Teachers highlighted that the course was performed more comfortably since students were familiarized with the process due to the application being carried out twice. Teachers pointed out that students’ familiarization with the GI method contributed to their active participation anytime in the lesson, the process within heterogeneous groups, and increased self-confidence as part of the learning-teaching processes and course preparation. These perspectives are in parallel with the results of the study conducted by Turaçoğlu (2011). One of the most important tasks a person has to accomplish is social development (Öztürk & Kutlu, 2017). Teachers also emphasized students’ sharing skills, preparation for the future, and managing and directing skills. Teachers indicated that the efficiency of the courses increased; therefore, student achievement was increased. When students were knowledgeable about the process of the course and comprehend its content well, the efficiency was optimized. A student who comprehended the process of the GI method well should attend the course preparedly and participate in the learning–teaching process within their group. This study revealed that students were able to reach this level in the second application. A student can get efficiency from a course if he or she preparedly attend the course and actively participate in the learning-teaching process. This study determined per interviews with the teachers that students became more efficient when they taught the topics themselves.

Additionally, teachers indicated that, since the students were knowledgeable about the method, carrying out the application twice saved time and created an environment in which the course would be taught more comfortably. Şimşek (2007) and Yıldırım (2006) proposed in their studies that insufficient time was one of the negative perspectives regarding these methods. By conducting the method twice in the classrooms, it was thought to contribute to the students in terms of saving time. Since time-saving efforts make it possible to allocate more time in which to teach the topic, learning efficiency can be increased. Teachers expressed that there were some difficulties in preparing the classroom physically before such application. These difficulties can stem from the wooden seats and tables in the classroom. Wooden rows were one-piece and big, therefore, it was difficult to move them, and students were unable to sit comfortably. Furthermore, the classroom was prepared for application during a five-minute period (the break time). In fact, if the wooden seats were to be changed with soft and beautiful portative chairs and the wooden rows-tables were changed to easily recyclable materials, this preparation time could be shortened. Açıkgenç, Köse, Günel, and Demirkol (2011), indicated that the physical conditions of schools and classrooms were among those factors greatly affecting educational quality. Specifically, due to the changes required by this age, designing learning environments according to the learners' characteristics—and making these environments easier for learners to construct their learning—plays a key role their education. Teachers stated that such applications should be performed by using different learning methods throughout all educational stages; in particular, they emphasized the importance of primary education regarding such applications because students acquire most of their educational habits during primary educational years, and because these habits subsequently shape their lives.

The researchers created a new experimental design to use in the second year of this study by revising the Solomon Four-group Experimental Design (Figure 1). A review of the relevant literature using Solomon Experimental Design found that it was used not only in educational sciences studies, but also in applied sciences such as psychology, medicine and food technology (Amirfakhraei, Ahadi, Keraskian, & Khalatbare, 2016; Bekker, Fischer, Tobi, & van Trijp, 2017; Holdnak, Clemons, & Bushardt, 1990; Retzbach, Retzbach, Maier, Otto, & Rahnke, 2013). These studies made only one implementation with the same sample. The new experimental group included in this study made it possible to make multiple implementations by adding groups to the same sample at different times, improve internal and external validity and comparing implementation results with each other. The researchers believe that this experimental model will be used in different research areas (e.g., psychology, genetics, biotechnology, biology, chemistry and engineering) in long-term studies in the future rather than being used only in the education studies for the implementation of different learning methods, and these studies will also make a great contribution to the literature.

Statement of Responsibility

Fulya Zorlu; conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing - original draft, writing - review & editing, visualization, supervision, project administration, funding acquisition. Fatih Sezek; conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing - original draft, writing - review & editing, visualization, supervision, project administration, funding acquisition.

References

Açıkgenç, A., Köse, M. R., Günel M., & Demirkol, B. (2011). *The characteristics of a 21st century student.* Ankara: MEB EARGED.

Aksoy, G., & Gürbüz, F. (2013). Group investigation teaching technique in Turkish primary science courses. *Balkan Physics Letters*, *21*(1), 99-106.

Amirfakhraei, A., Ahadi, H., Keraskian, A., & Khalatbareh, J. (2016). Effectiveness of acceptance and commitment therapy (act) on dysfunctional communicative attitude (dca) of couples suffering diabetes in bandar abbas. *Turkish Online Journal of Design Art and Communication,* *6*, 1665-1672. http://dx.doi.org/10.7456/1060AGSE/048

Andrews, K. E., Tressler, K. D., & Mintzes, J. J. (2008). Assessing environmental understanding: An application of the concept mapping strategy. *Environmental Education Research,* *14*(5), 519-536. http://dx.doi.org/10.1080/13504620802278829

Astra, I. M., Wahyuni, C., & Nasbey, H. (2015). Improvement of learning process and learning outcomes in physics learning by using collaborative learning model of group investigation at high school (grade X, SMAN 14 Jakarta). *Journal of Education and Practice, 6*(11), 75-80.

Avcı, S. (2002). *Active learning [Aktif öğrenme]*. Retrieved from: http://www.Mlokurs.Virtuale.Net

Ayas, A., & Özmen, H. (2002). A study of students' level of understanding of the particulate nature of matter at secondary school level, *Boğaziçi Üniversitesi Eğitim Dergisi*, *19*(2), 45-60.

Aydoğdu, B., & Ergin, Ö. (2009). The development of science process skills scale toward "electricity in our life" units of science and technology course. *New World Sciences Academy 4*(2), 296-316.

Ayres, J., Hopf, T., & Will, A. (2000). Are reductions in CA an experimental artifact? A Solomon four-group answer. *Communication Quarterly, 48*(1), 19-26. http://dx.doi.org/10.1080/01463370009385576

Babbie, E. (2013). *The basis of social research* (16th ed.). Belmont, USA: Wadsworth Cengage Learning.

Bahadır, E. (2011). *The investigation of the effects of the usage of cooperative-based scientific letters on students? attitudes, achievements, and scientific literacies for understanding states of matter and heat unit at grade eight* (Unpublished master's thesis). Erzincan University, Erzincan.

Başdağ, G. (2006). *2000 yılı fen bilgisi dersi ve 2004 yılı fen ve teknoloji dersi öğretim programlarının bilimsel süreç becerileri yönünden karşılaştırılması* (Unpublished master's thesis). Gazi University, Ankara.

Bayrakçeken, S., Doymuş, K., & Doğan, A. (2013). *Cooperative learning model and application*. Ankara: PegemA.

Bekker G. A., Fischer, A. R. H., Tobi, H., & van Trijp, H. C. M. (2017). Explicit and implicit attitude toward an emerging food technology: The case of cultured meat. *Appetite, 108*, 245-254. http://dx.doi.org/10.1016/j.appet.2016.10.002

Bıyıklı, F. (2015). *The effect of cooperative learning method on students achievements, idendifications and using ability of laboratory equipments in General physics laboratory-I course* (Unpublished master's thesis). Kastamonu University, Kastamonu.

Bilgin, İ., & Karaduman, A. (2005). Investigating the effects of cooperative learning on 8 grade students' attitudes toward science. *İlköğretim-Online, 4*(2), 32-45.

Bischoff, P. J. (2006). The role of knowledge structures in the ability of preservice elementary teachers to diagnose a child's understanding of molecular kinetics. *Science Education, 90*(5), 936-951.

Bozdoğan, A. E., Taşdemir, A., & Demirbaş, M. (2006). The effect of cooperative learning method in science education on improving the students' science process skills. *The Inonu University Journal of the Faculty of Education, 7*(11), 23-36.

Braver, M. W., & Braver, S. L. (1988). Statistical treatment of the Solomon four-group design: A meta-analytic approach. *Psychological Bulletin, 104*(1), 150-154. http://dx.doi.org/10.1037/0033-2909.104.1.150

Büyüköztürk, Ş. (2014). *Data analysis handbook for social sciences* [Sosyal bilimler için veri analizi el kitabı], (19th ed.) Ankara.

Campbell, D. T., & Stanley J. C. (1980). *Experimental and quasi-experimental designs for research*. Chicago: Chicago Rand McNally College.

Chatila, H., & Al Husseiny, F. (2017). Effect of cooperative learning strategy on students' acquisition and practice of scientific skills in Biology. *Journal of Education in Science, Environment and Health, 3*(1), 88-99.

Christensen, L. B., Johnson, R. B., & Turner, L. A. (2015). *Research methods design and analysis*. Cambridge: Pearson.

Creswell, J. W. (2003). *Research design. Qualitative, quantitative and mixed methods approaches*, (2nd ed.). Thousand Oaks, CA: Sage.

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*, (4th ed.). Boston: Pearson.

Çepni, S., Ayas, A., Johnson, D., & Turgut, M. F. (1996). *Physics teaching [Fizik öğretimi]*. Ankara: Milli Eğitimi Geliştirme Projesi Hizmet Öncesi Öğretmen Eğitimi Deneme Basımı.

Çepni, S., Aydın, A., & Ayvacı, H. Ş. (2000). Dört ve beşinci sınıflarda fen bilgisi programındaki fizik kavramlarının öğrenciler tarafından anlaşılma düzeyleri, *H.Ü. Eğitim Bilimleri Sempozyumu*, Ankara: Hacettepe Üniversitesi.

Damini, M. (2014). How the group investigation model and the six-mirror model changed teachers' roles and teachers' and students' attitudes towards diversity. *Intercultural Education, 25*(3), 197-205. http://dx.doi.org/10.1080/14675986.2014.917794

Dikel, S. (2012). *Informing of science and technology teachers about cooperative learning method, applications of this method in the class and evaluating the obtained results: Example of Erzurum city* (Unpublished master's thesis). Atatürk University, Erzurum.

Dirlikli, M., Aydın, K., & Akgün, L. (2016). Cooperative learning in Turkey: A content analysis of theses. *Educational Sciences: Theory and Practice*, *16*(4), 1251-1273. http://dx.doi.org/10.12738/estp.2016.4.0142

Doymuş, K. (2012). *Informing science and technology teachers about collaborative learning method, applying this method to class and evaluating the obtained results* (110K252). TUBITAK Project.

Doymuş, K., Şimşek, Ü., & Karaçöp, A. (2009). The effects of computer animations and cooperative learning methods in micro, macro and symbolic level learning of states of matter. *Eurasian Journal of Educational Research (EJER)*, *36*, 109-128.

Ebrahim, A. (2012). The effect of cooperative learning strategies on elementary students' science achievement and social skills in Kuwait. *International Journal of Science and Mathematics Education, 10*(2), 293-314. http://dx.doi.org/10.1007/s10763-011-9293-0

Efe, R., Hevedanlı, M., Ketani, Ş., Çakmak, Ö., & Efe, H. (2008). *Cooperative learning: Theory and practice*. Ankara: Eflatun.

Er Nas, S. (2013). *Madde ve ısı ünitesindeki kavramların günlük hayata transfer edilmesinde derinleştirme aşamasına yönelik geliştirilen kılavuzun etkililiğinin değerlendirilmesi (Unpublished doctoral thesis)*. Karadeniz Teknik University, Trabzon.

Ergin, M. (2007). *Effect of cooperative learning method on student achievement and attitudes in teaching topics of primary school sciences and technology* (Unpublished master's thesis). Selçuk University, Konya.

Ertosun, Ö. G., Erdil, O., Deniz, N., & Alpkan, L. (2015). Positive psychological capital development: a field study by the Solomon four group design. *International Business Research*, *8*(10), 102. http://dx.doi.org/10.5539/ibr.v8n10p102

Gay, L. R., Mills, G. E., & Airasian, P. W. (2012). Action research (Chapter 20). In: *Educational research: Competencies for analysis and applications* (10th ed.). Boston: Pearson.

Geban, Ö., Aşkar, P., & Özkan, I. (1992). Effects of computer simulations and problem-solving approaches on high school students. *Journal of Educational Research, 86*(1), 5-10.

Güler, B., & Şahin, M. (2015). The effect of blended learning method on preservice elementary science teachers' attitudes toward technology, self-regulation and science process skills. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education*, *9*(1), 108-127.

Halloun, I. A. (2007). *Modeling theory in science education*. Netherlands: Springer Publishers.

Halloun, I. A. (2011). *Modeling and student learning in science education*. In M. S. Khine & I. M. Sale. (Eds.), *Models and modeling: Cognitive tools for scientific enquiry*. Springer Science & Business Media.

Harwell, M. R. (2011). Research design: Qualitative, quantitative, and mixed methods. In C. Conrad & R.C. Serlin (Eds.), *The Sage handbook for research in education: Pursuing ideas as the keystone of exemplary inquiry* (2nd ed.). Thousand Oaks, CA: Sage.

Hertz-Lazarowitz, R., & Calderon, M. (1994). Implementing cooperative learning in the elementary schools: The facilitative voice for collaborative power. S. Sharan (Ed.), In *Handbook of cooperative learning methods*, Newyork: Greenwood.

Hofstein, A., Navon, O., Kipnis M., & Naaman, M. (2005). Developing students' ability to ask more and better questions resulting from inquiry-type chemistry laboratories. *Journal of Research in Science Teaching, 42*(7), 791-806. http://dx.doi.org/10.1002/tea.20072

Holdnak, B. J., Clemons, T. C., & Bushardt, S. C. (1990). Evaluation of organization training by the Solomon four group design: A field study in self-esteem training. *Journal of Managerial Psychology, 5*, 25-32. http://dx.doi.org/10.1108/02683949010136251

Hosseini, S. M. H. (2014). Competitive team-based learning versus group investigation with reference to the language proficiency of Iranian EFL intermediate students. *International Journal of Instruction, 7*(1), 177-188.

Iswardati, I. (2016). The Implementation of Group Investigation to improve the students' speaking skill. *Dinamika Ilmu, 16*(2), 245-261.

Jacobi, A., Martin, J., Mitchell, J., & Newell, T. (2004). Work on progress: A concept ınventory for heat transfer. *Asee/Ieee Frontiers in Education Conference*.

Jalilifar, A. (2010). The effect of cooperative learning techniques on college students' reading comprehension. *An International Journal of Educational Technology and Applied Linguistics, 38*(1), 96-108. http://dx.doi.org/10.1016/j.system.2009.12.009

Johnson, B., & Christensen L. (2004). *Education research: Quantitative, qualitative, and mixed approaches.* (2nd ed.). Boston: Allyn and Bacon.

Johnson, R. T., Johnson, D. W., & Holubec, E. J. (1994). *New circles of learning: cooperation in the classroom and school*. Alexandra, VA, USA: Association for Supervision & Curriculum Development (ASCD).

Kala, N. (2014). Deneysel araştırma [Experimental research]. In B. Johnson & L. Christensen, (S. B. Demir, (Trans. Ed.)), *Educational research- quantitative, qualitative, and mixed approaches* (pp.282-316). Ankara: Eğiten Kitap.

Karasar, N. (2016). *Scientific research method*. Ankara: Nobel.

Kaufman, S. (2014). Learning together. *Schools: Studies in Education, 11*(2), 263-305. doi: 10.1086/678219

Köseoğlu, F., & Tümay, H. (2015). *Constructivism in science education and new teaching methods* [*Fen eğitiminde yapılandırıcılık ve yeni öğretim yöntemleri].* Ankara: Palme.

Kutluca, T. (2014). Data Collection Methods [Veri Toplama Yöntemleri]. In B. Johnson and L. Christensen (S. B. Demir (Trans. Ed.)) *Educational research- quantitative, qualitative, and mixed approaches* (pp. 282-316). Ankara: Eğiten Kitap.

Lazarowitz, R., Hertz-Lazarowitz, R., Khalil, M., & Ron, S. (2013). Designing cooperative learning in the science classroom: integrating the peer tutoring small investigation group (PTSIG) within the model of the six mirrors of the classroom model. In *Bulgarian Comparative Education Society, Paper presented at the Annual International Conference of the Bulgarian Comparative Education Society* 14-17 Mayıs 2013. Bulgaristan: Plovdiv.

Lubben F., Netshisaulu T., & Campbell B. (1999). Culture and comparative studies students' use of cultural metaphors and their scientific understandings related to heating. *Science Education, 83*(6), 761–774.

McMillan, J. H. (2008). *Educational research: Fundamentals for the consumer*, (5th ed.). Boston, MA: Pearson Education.

MEB (Ministry of National Education) (2013). *İlköğretim kurumları fen bilgisi dersi öğretim programı [Primary education institutions science curriculum teaching program]*. İstanbul: Milli Eğitim.

Mehalik, M. M., Doppelt, Y., & Schuun, C. D. (2008). Middle-school science through design-based learning versus scripted inquiry: Better overall science concept learning and equity gap reduction. *Journal of Engineering Education, 97*(1), 71-85.

Mitchell, M. G., Montgomery, H., Holder, M., & Stuart, D. (2008). Group investigation as a cooperative learning strategy: An integrated analysis of the literature. *Alberta Journal of Educational Research, 54*(4), 388-395.

Neuman, W. L. (2014). *Methods of social research-2. Qualitative and quantitative approaches*. S. Özge (Trans. Ed.). Ankara: Siyasal.

Okur-Akçay, N., & Doymuş, K. (2012). The effects of group investigation and cooperative learning techniques applied in teaching force and motion subjects on students' academic achievements. *Journal of Educational Sciences Research, 2*(1), 100-116.

Öztürk, N., & Kutlu, M. (2017). The impact of friendship skills psycho-education on the friendship quality of 9-12 year-old students. *Education and Science, 42*(191), 397-413. http://dx.doi.org/10.1002/cd.3

Rabgay, T. (2018). The effect of using cooperative learning method on tenth grade students' learning achievement and attitude towards biology. *International Journal of Instruction, 11*(2), 265-280. http://dx.doi.org/10.12973/iji.2018.11218a.

Retzbach, J., Retzbach, A., Maier, M., Otto, L., & Rahnke, M. (2013). Effects of repeated exposure to science TV shows on beliefs about scientific evidence and interest in science. *Journal of Media Psychology, 25*(1), 3-13. http://dx.doi.org/10.1027/1864-1105/a000073

Sancı, M., & Kılıç, D. (2011). The effect of jigsaw and group research techniques applied in elementary school fourth grade science and technology course teaching on students' academic achievement. *Journal of Educational and Instructional Studies in the World, 1*(1), 80-92.

Sangadji, S. (2016). Implementation of cooperative learning with group investigation model to improve learning achievement of vocational school students in Indonesia. *International Journal of Learning & Development, 6*(1), 91-103.

Sawilowsky, S., Kelley, D. L., Blair, R. C., & Markman, B. S. (1994). Meta-analysis and the Solomon four-group design. *The Journal of Experimental Education, 62*(4), 361-376. http://dx.doi.org/10.1080/00220973.1994.9944140

Schwarz, B. B., de Groot, R., Mavrikis, M., & Dragon, T. (2015). Learning to learn together with CSCL tools, *International Journal of Computer-Supported Collaborative Learning, 10*(3), 239-271. http://dx.doi.org/10.1007/s11412-015-9216-0

Schunk, D. H. (2011). *Learning theories an educational perspective* (Trans. M. Şahin,) Ankara: Nobel Yayıncılık.

Sezek, F., Zorlu, Y., & Zorlu, F. (2015). Examination of the factors influencing the scientific process skills of the students in the elementary education department. *Journal of Education Faculty, 17*(1), 197-217.

Sharan, Y. (2015). Meaningful learning in the cooperative classroom, *International Journal of Primary, Elementary and Early Years Education 3-13, 43*(1), 83-94.

Sharan, S., & Sharan, Y. (1992). *Expanding cooperative learning through group investigation*. New York: Teachers College Press.

Şimşek, Ü. (2007). *The effects of the Jigsaw and learning together techniques applied in solutions and chemical equilibrium subjects on learning of the particulate nature of matter by the students and their the academic achievements* (Unpublished doctorate thesis). Atatürk University, Erzurum.

Şimşek, Ü., Doymuş, K., & Bayrakçeken, S. (2006). The effect of cooperative learning method on rural area student's science achievement and their attitudes towards science course. *Education and Science, 31*(140), 3-9.

Şimşek, Ü., Doymuş, K., & Karaçöp, A. (2008). The effect of group investigation technique applied in solutions unit on the learning of the particulate nature of matter by the students and their academic achievements. *Bayburt University Journal of Educational Faculty, 3*(1-2), 87-99.

Şimşek, Ü., Doymuş, K., & Şimşek, U. (2008). A review on cooperative learning method: II. The application in classroom of cooperative learning method. *Erzincan University Journal of Educational Faculty, 10*(1), 123-142.

Şimşek, Ü., Doymuş, K., Doğan, A., & Karaçöp, A. (2009). The influence of two different techniques of cooperative learning on the academic achievement of the students and their meaning in the partial structure of the material. *Gazi University Journal of Educational Faculty, 29*(3), 763-791.

Sinan, O., & Uşak, M. (2011). Evaluating of prospective biology teachers' scientific process skills. *Mustafa Kemal University Journal of Social Sciences Institute, 8*(15), 333-348.

Slavin, R. E. (1999). Comprehensive approaches to cooperative learning. *Theory into Practice, 38*(2), 74.

Solomon, R. L. (1949). An extension of control group design. *Psychological Bulletin, 46*(2), 137-150. http://dx.doi.org/10.1037/h0062958

Solomon, R. L., & Lessac, M. S. (1968). A control group design for experimental studies of developmental processes. *Psychological Bulletin, 70*(31), 145-150. doi: 10.1037/h0026147

Stephan, J. (1994). *Targeting students science misconceptions: physical science activities using the conceptual change model*. Riverview, Florida: The Idea Factory.

Tan, I. G. C., Sharan, S., & Lee, C. K. E. (2007). Group investigation effects on achievement, motivation, and perceptions of students in Singapore. *The Journal of Educational Research, 100*(3), 142-154. http://dx.doi.org/10.3200/joer.100.3.142-154

Turaçoğlu, İ. (2011). Pre-service teachers' self-evaluations towards group investigation technique. *Buca Faculty of Education Journal, 31*, 39-47.

Ünal-Çoban, G. (2009). *The effects of model based science education on students? Conceptual understanding, science process skills, understanding of scientific knowledge and its domain of existence: The sample of 7th grade unit of light* (Unpublished doctorate thesis). Dokuz Eylül University, İzmir.

Weinrich, S. P., Seger, R., Curtsinger, T., Pumphrey, G., NeSmith, E.G., & Weinrich, M. C. (2007). Impact of pretest on posttest knowledge scores with a Solomon four research design. *Cancer Nursing,* 30, 16-28. http://dx.doi.org/10.1097/01.ncc.0000290820.22195.5b

Yıldırım, K. (2006). *The effects of cooperative learning method supported by multiple intelligence theory on elementary school fifth grade students' academic achievement, self-esteem and retention* (Unpublished master's thesis). Çukurova University, Adana.

Zorlu, F., Zorlu, Y., Sezek, F., & Akkuş, H. (2014). Secondary eighth graders' the scores of scientific process skills and their relationship with the scores of theirs placement test results. *Journal of EKEV Academy, 59*(59), 519-532.

Zorlu, Y. (2016). *Effects of activities based on modeling learning method and cooperative learning model of students in elementary science and technology course* (Unpublished doctorate thesis). Atatürk University, Erzurum.

Zorlu, Y., & Sezek, F. (2016). The investigation of effects to learning together method with modeling based learning method on constructivist learning environment. *Journal of EKEV Academy, 20*(68), 415-430. http://dx.doi.org/10.17753/Ekev708

Zorlu, Y., & Sezek, F. (2019). Investigation of the effects of group research method of applying modeling based teaching method in the particle structure and properties of matter unit on constructivist learning. *Sakarya University Journal of Education, 9*(3), 455-475.