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Effectiveness of Guided Inquiry Learning Strategies on Middle School Students' Achievement and Science Self-Efficacy

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Abstract

The aim of this study is to investigate the effect of guided inquiry-based learning approach on students' academic achievement and science self-efficacy. In the study, a quasi-experimental model with pretest-posttest control group was used. The research was carried out with 40 students studying in a public school located in the southeast of Turkey. Within the scope of the application, while the activities in accordance with the guided inquiry-based learning approach were carried out in the experimental group, the Science Curriculum (MoE, 2018) was applied in the control group. Strength and energy achievement test and science self-efficacy scale were used as data collection tools in the study. As a result of the research, it was concluded that guided inquiry-based learning approach had a significant effect on students' academic achievement and self-efficacy. In the study, various suggestions were made for researchers.

Keywords: Guided inquiry-based science, self-efficacy, science education

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Introduction

The rapid economic, social, scientific and technological developments affect the society and the individual significantly. In order to create a strong future, countries organize various educational reforms in order to adapt their education systems to this rapid change and development. The educational reforms and the constructivist teaching theory are based on. Inquiry-based learning, which is one of the teaching practices of the constructivist approach, has been tried to be prioritized as a basic approach in the science curriculum updated in 2013 (MoE, 2013). The aim of this program is to raise scientifically literate individuals. It is thought that every citizen should be educated as a science literate and science lesson is important in this process. Many methods are applied in order to raise individuals as scientifically literate. One of the most important of these methods is inquiry-based teaching method. Inquiry-based learning is handled as a process of "research and inquiry, not only as exploration and experimentation, but also as explanation and making claims" in the science curriculum from the 3rd to the 8th grade (MoE, 2013). Inquiry-based learning is a process in which students want to discover all the situations and objects around them; they make effective claims by explaining the nature and physical world around them with strong justifications; they grow up as individuals who are excited and appreciate science.

It is necessary to define inquiry and what it looks like in the classroom in order to comprehend the impact of an inquiry-based approach to instructional techniques. According to Pedaste et al. (2015), inquiry is a tactic that enables students to act like scientists in the field by adopting the same procedures and methods that scientists use to create knowledge. In essence, students are using problem-solving to increase their knowledge. They can test them out in the lab and come up with queries concerning phenomena.In short, it is a learning approach in which the student is at the center and she/he creates the knowledge in her/his own mind by doing-living-thinking like a scientist (MoE, 2013). Inquiry and the National Science Education Standards (National Research Council [NRC], 2000) define inquiry as a

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process. In the literature, it has been stated that since inquiry is used both as a teaching method and in the sense of doing science, it causes confusion in the definition of inquiry. Inquiry-based science teaching includes defining scientific inquiry problems, testing hypotheses, solving problems, conducting scientific research, and sharing scientific evidence (NRC, 2000). Inquiry-based science teaching is the increase in students' ability to understand the nature of science and to do science by asking questions (inquiry), planning, designing, using data, researching, analyzing and communicating. Inquiry-based learning is viewed as a learning process by which students ask questions, research, and analyze data. Research inquiry approach has the potential of learning by doing science, learning science and learning how to do science (NRC, 2000). In the American National Science Education Standards determined by the National Research Council (NRC), the research-based learning approach is defined as follows: It is a multidimensional process in which observations are made by students, questions are asked, existing information about the subject is searched from books and other sources, research is planned, information is compared with experimental findings, tools and materials are used to collect; analyzing and interpretting information, assumptions, explanations and results are put forward and discussed. (NRC, 2000). By distinguishing between various inquiry styles, Wang et al. (2022) expand on the definition of inquiry-based learning. Both organized and open-ended questions can be presented to pupils by teachers. According to Nicol (2021), open inquiry is when pupils conduct research through unguided exploration. Guided inquiry, sometimes referred to as structured inquiry, gives students the freedom to investigate and engage in critical thinking while offering the teacher as much assistance as the students require (Nicol, 2021). Inquiry-based method critics usually focus on the learner's prior knowledge; without this foundation, students may find it difficult to comprehend the tasks they are given (Kirschner et al., 2006; Mayer, 2004). According to Spaulding (2001), there are three types of inquiry-based learning: structured inquiry, guided inquiry and open inquiry. Structured inquiry consists of students' reactions to what the teacher tells. In this approach, since the problems to be solved by the students, the solution method and the necessary materials are provided by the teacher, the students are only expected to find the results they will discover. In guided inquiry, the teacher reveals the problem situation that the students will solve and directs the students to the solution of the problem with various questions. The solution method is left open for students to determine according to their own preferences. Finally, open inquiry is research in which students develop a research question and prepare an implementation process that includes a data collection plan. In open research, the student does the research without teacher guidance. Schwab (1966) explained research inquiry-based learning at three levels that move progressively from the active role of the teacher to the student's activity: Level 1 Structured Inquiry: The problem and the solution are given to the student. The student knows the result of the problem. Level 2. Guided Inquiry: The problem is given to the student. The student reaches the result by determining the solution way of the problem himself. Level 3. Open Inquiry: the student determines all the stages himself. Structured Inquiry is the most used level of traditional teacher-centered approach. The teacher's instructions are given in a book called a "cookbook". It is a research-inquiry type in which the process steps with instructions are followed. High-level thinking skills cannot be expected in this inquiry type (Keller, 2001). The concept or principles are presented to the students by the teacher and the student is asked to complete his research by following carefully planned steps for validation. Since the student knows in advance what the result will be, he is not excited about the result he has obtained and doing research. Activities carried out to verify the questions with known answers at the structured inquiry level by following the given steps do not improve students' ability to conduct scientific research (Furtak, 2006). In Guided Inquiry, the teacher plays the role of helping students in their research. The teacher gives questions and basic information about the subject. The teacher encourages the students in the guided inquiry method and helps them to reach the answers (Furtak, 2006). In the guided inquiry type, activities related to the subject should be prepared in advance, and the thinking questions and problems that will enable the student to think should be at a level that develops the students' analysis, synthesis and evaluation skills. In guided inquiry, the student investigates the questions and method given by the teacher and then determines the process of the research and the solutions. Although the questions are given by the teacher in guided inquiry, students actively manage the inquiry process. For this, the teacher must have a good idea of what results will emerge. This research was carried out according to the guided inquiry level, one of the levels suggested by Schwab.

Self-efficacy belief, which is one of the basic concepts of Social Learning Theory, is defined as "the individual's self-judgment about his capacity to organize and successfully perform the necessary

activities to show a certain performance" (Bandura, 1998). Bandura (1998) explains self-efficacy belief with individuals' achievements, vicarious experiences, verbal persuasion, physiological and emotional states. Accordingly, success depends not only on having the necessary skills to do a job, but also on the effective use of the skill. Social learning theory suggests that a person's belief in performing a certain action or behavior will determine the behavior change or performance of that action (Tobin, Tippins, & Gallard, 1994). The higher our confidence in ourselves to be able to accomplish an action, the lower our anxiety level will be and the more likely we will be to take that action. Zusho and Pintrich (2003) defined 'Self-efficacy' as being aware of and believing in one's own abilities for performance and action. Self-efficacy belief affects the goals that individuals aim for, how much they can try to reach these goals, how much they can struggle with the difficulties they face to reach their goals, and their reactions when they fail to reach these goals (Çubukçu, & Girmen, 2007). Pajares (1996) stated that self-efficacy is a product of the individual's perception of what he can achieve by using his own abilities, and that self-efficacy belief is the subject of various studies that affect many aspects of the individual. Pajares (1996) stated that people with high self-efficacy beliefs are more resilient in being successful in a job, show persistence when faced with adversity, and are stubborn and patient. Göller (2015) defined self-efficacy belief as people's beliefs and perceptions about initiating, continuing and successfully completing an action related to a certain action. Inquiry-based self-efficacy is related to the effort students put into using their inquiry skills and to feel competent in using these skills. Students with high inquiry-based self-efficacy beliefs are expected to feel competent during the questioning process, to show sufficient effort and not to give up on difficulties (Feyzioğlu, 2019). In this study, it was aimed to determine the effect of guided inquiry method on the success and self-efficacy skills of the students in the subject of "strength and energy" placed in the 7th grade science curriculum. For this purpose, answers were sought to the following research questions:

1. What is the effect of guided inquiry learning on students' academic achievement?

2. What is the effect of guided inquiry learning on students' science self-efficacy?

Method

In the research, a quasi-experimental method with pretest-posttest control group was used. The reason for choosing the quasi-experimental method is that it is not possible for the students in the sample to be assigned to the experimental and control groups impartially. The experimental view of the research is presented in Table 1.

Table 1

Implementation Process of The Research

Groups	Pretest	Application	Posttest
Experimental group	Achievement test Self efficacy	Guided inquiry	Achievement test Self efficacy
Control group	Achievement test Self efficacy	Science Curriculum (MoE, 2018)	Achievement test Self efficacy

Guided inquiry learning was applied to the experimental group. In the control group, on the other hand, the Science Curriculum (MoE, 2018) traditional method was used, in which the narrative method was used more and the demonstration and closed-ended experiments based on the activities in the textbook were preferred more.

Participants

The study was carried out with the participation of 7th grade students studying in a public secondary school in the southeast of Turkey in the fall semester of the 2021-2022 academic year. The groups participating in the study were determined by the school administration as the experimental (20) and control (20) groups from the pre-formed classes in the form of random distribution.

Data Collection Tools

In the research, "Science Self-Efficacy Scale" and "Strength and Movement Academic Achievement Test" were used as data collection tools. The Science Self-Efficacy Scale is a Likert-type scale consisting of 36 items. In the study, the reliability coefficient was found to be 0.917 (Yıldırım, 2017). In the research, "Strength and Movement Academic Achievement Test" was applied in order to determine the effectiveness of process-oriented guided inquiry learning on the 'force and energy' unit of students' learning levels. The achievement test developed by Kınık (2015) consists of 19 multiple-choice questions. The Cronbach Alpha value of the test was found to be 0.820 and the KR-20 coefficient as 0.835 (Kınık, 2015).

Application

In the application process of the study, while the Science Curriculum (MoE, 2018) traditional method was taught by the researcher in the control group, the lessons were taught according to the guided inquiry method in the experimental group. In the control group, the traditional method lesson plans were prepared by the researcher based on the activities and experiments according to the science curriculum created by the Ministry of National Education. In the control group, the lessons were taught by paying attention to the fact that the textbook was in the center, that the students could reach the information by reading or listening to the teacher, and that the questions were asked by the teacher and had only one answer. The lessons were mainly in the form of demonstration experiments in which the presentation and question-answer method was used and the experiments were performed by the teacher, and the teacher-centered traditional teaching method was applied. In the first stage, the students in the experimental group were informed about the definition of doing research, its benefits, stages, identifying problems, establishing hypotheses, data collection techniques, data analysis, testing hypotheses, presentation of the obtained information, research ethics. In the experimental group, the students were divided into heterogeneous groups of 4-5 people. At the beginning of each research process, the lesson was started with questions and case studies that would attract the attention of the students. Afterwards, it was tried to reveal the pre-knowledge of the subject by enabling the students to brainstorm on the subject. After the study groups were formed, the worksheet titled "I'm Doing Research" was distributed to the students, showing the steps to be followed during the research and guiding the students in this regard. In order for the students to get used to the process and to have an idea about how the studies will be carried out, a common research topic was determined for all groups for the first application. The process was carried out jointly by performing the same procedures (same research problem, same hypotheses, same method-techniques, etc.) in all groups under the guidance of the teacher. After the second week, each group determined their own research topic, research problem and hypotheses in line with the achievements. After the research problem they determined with their group friends, the students determined their research hypotheses by brainstorming with their friends. In this process, the teacher guided all the groups and guided the groups with appropriate feedback for the process to proceed correctly. The application process was guided by the cooperation of the teacher and the researcher, the application and student studies were followed by the researcher and control was provided to ensure that the studies are carried out in accordance with the purpose. In line with the received opinions, the joint decisions taken in the group shaped the process. The studies prepared by the group were presented in the class. The application process was completed by applying simultaneous post-tests in the experimental and control groups.

Analysis of Data

The data collected through the academic achievement test (pretest-posttest) and self-efficacy test (pretest-posttest) during the research were analyzed with the help of the SPSS program. In the research analysis, first of all, it was examined whether the data showed a normal distribution. Since the scores of the tests showed a normal distribution, parametric tests were used to find answers to the research questions. Independent groups t-test analysis was conducted to determine whether there was a significant difference between the pre-test academic achievements of the experimental and control groups. As a result of the independent groups t-test analysis, a significant difference was found between the pre-test scores of the groups' self-efficacy skills. Therefore, ANCOVA analysis was performed, and averages adjusted with the Bonferroni test were included. ANCOVA analysis makes it possible to determine the true effect of the experiment by eliminating the external factors that cannot be controlled by the research study with a linear regression method in cases where there are differences between the groups at the beginning of an experimental application (Büyüköztürk, 2010).

Results

For the purposes of the research, it was examined whether there was a significant difference between the academic achievement and self-efficacy of the experimental and control groups. In the study, descriptive statistical findings related to the experimental and control groups were examined (Table 2).

Table2

Descriptive Statistics of Achievement and Self-Efficacy Scales

		Achievement	Self-efficacy
Pre-test	**M**	30.18	99.3
	Median	28.60	101.5
	Variance	304.3	325.9
	Min.	7.1	57
	Max.	78.5	137
	Skewness	.711	-.091
	Kurtosis	.051	.076
Post-test	**M**	53.43	123.1
	Median	50.0	124.0
	Variance	527.2	234.1
	Min.	21.4	87
	Max.	100	156
	Skewness	.309	-.170
	Kurtosis	-.149	-.294

When the descriptive statistics of academic achievement and self-efficacy scales are evaluated in Table 2, pre-test skewness (.711) and kurtosis (.051), post-test skewness (.309) and kurtosis (-.149); In the self-efficacy scale, pre-test skewness (-.091) and kurtosis (.076), post-test skewness (-.170) and kurtosis (-.294) values were calculated and it was seen that the data showed a normal distribution. After it was determined that the data showed a normal distribution in the study, the academic achievement pre-test scores of the experimental and control groups were examined with the independent samples t-test.

Table 3

Group Statistics of Pre-Test for Comparison and Experimental Groups

Test	Group	n	M	ss	sd	t	p
Achievement	Experimental	20	27.84	15.52	38	-.846	.403
	Control	20	32.52	19.29			

When the results in Table 3 are examined, it is seen that the academic achievement pre-test mean of the experimental group was 27.84 (sd=15.52) and the pre-test mean of the control group was 32.52 (sd=19.29). According to the pre-test results, there was no statistically significant difference,at the 0.05 level,between the pre-test academic achievement scores of the experimental and control groups (t=-.846, p>0.05).

In order to examine the effect of guided inquiry learning on the academic achievement of the students, the academic achievement post-test data of the experimental and control groups were analyzed with the independent t-test (Table 4).

Table 4
Independent Samples T-Test of Achievements' Post-Test for Comparison and Experimental Groups

	Group	n	M	ss	sd	t	p
Achievement	Experimental	20	71.59	15.89	38	5.828	.000*
	Control	20	43.29	13.80			

*p<0.05

When the independent t-test results regarding the difference between the academic achievement post-test scores of the experimental and control group students are examined, it is seen that the post-test achievement mean score of the experimental group is 71.59 (sd=15.89), and the post-test achievement mean score of the control group is 43.29 (sd=13.8) (t=5.828, p<0.05). When Table 3 is examined, it has been determined that there is a significant difference between the post-test mean of the experimental and control groups in favor of the experimental group. With this result, it can be deduced that guided inquiry learning improves students' academic achievement.

In line with the second aim of the study, the mean and standard deviation values of the pre-test and post-test scores of the science self-efficacy skills of the experimental and control groups were examined (Table 5).

Table 5
Mean and Standard Deviation Values of The Groups' Self-Efficacy Pretest-Posttest Scores

Self-efficacy	Experimental group			Control group		
	n	M	ss	n	M	ss
Pre-test	20	93.45	16.80	20	105.20	17.71
Post-test	20	129.95	12.37	20	116.35	15.16

Table 5 shows how much the self-efficacy pre- and post-test mean scores of the groups have changed. The self-efficacy pre-test mean score of the experimental group students (M=93.45), the self-efficacy pre-test mean score of the control group students (M=105.2); The self-efficacy post-test mean score of the experimental group students was calculated as (M=129.95), and the self-efficacy post-test mean score of the control group students was calculated as (M=116.35). Independent groups t-test analysis was performed to determine whether there was a significant difference between the science self-efficacy pre-test scores of the groups and the findings are shown in Table 6.

Table 6
Group Statistics of Self Efficacy Pre-Test for Comparison and Experimental Groups

Test	Group	n	M	ss	sd	t	p
Self-efficacy	Experimental	20	93.45	16.8	38	-2.152	.038*
	Control	20	105.2	17.71			

*p<0.05

It was calculated that the self-efficacy pre-test mean score of the control group (M=105.2) was higher than the self-efficacy pre-test mean score (M=93.45) of the experimental group. As a result of the independent groups t-test analysis, the difference between the pre-test scores of the groups was found to be statistically significant ($t_{(38)}$=-2.152; p=.038). ANCOVA analysis was performed to determine to what extent the post-test scores differed due to the difference between the pre-test scores of the groups, and whether the difference resulting from the change was significant. Averages corrected with the Bonferroni test are included. Self-efficacy post-test scores were taken as covariate in ANCOVA analysis. The results are shown in Table 7.

Table 7
Ancova Results of Post Test Means Adjusted According to Self Efficacy Pre-Test For Experimental and Control Groups

Source of variance	Sum of squares	df	Mean squares	F	p
Self-efficacy pre-test	404.21	1	404.21	2.175	.149
Groups	2230.69	1	2230.69	12.00	.001
Error	6877.28	37	185.87		
Total	615768.0	40			
Adjusted Total	9131.10	39			

In Table 7, ANCOVA analysis results were adjusted according to the pre-test scores, and the main effect of grouping of the post-test scores was found to be significant ($F_{(1-37)}$=12.00, p=.001). In other words, ANCOVA analysis was performed with the average of the post-test scores of the groups. As a result of this, a significant difference was determined in favor of the experimental group students according to the common effect results. In order to express the determined significant difference more clearly, the final status of the mean and adjusted mean values of the groups' self-efficacy post-test scores are given in Table 8.

Table 8.
Descriptive Statistics of The Groups' Post-Test Scores

Group	N	M	Adjusted means
Experimental	20	129.95	131.06
Control	20	116.35	115.24

According to the adjusted pre-test mean scores of the experimental and control groups, it was determined that the self-efficacy skills of the experimental group changed more positively than the control group. In other words, it was determined that the guided inquiry method had a more positive effect on students' science self-efficacy skills than the traditional teaching method.

Discussion, Conclusions, and Suggestions

In the study, the effect of guided inquiry-based learning on secondary school students' academic achievement and self-efficacy skills was examined. As a result of the analysis of the data obtained from the study, there was no significant difference between the experimental and control group pre-tests. According to this result, it can be said that the experimental and control groups were similar in terms of academic achievement before starting the application. When the post-test success scores of the experimental and control groups applied at the end of the process were analyzed, it was determined that there was a significant difference between the groups and this difference was in favor of the experimental group. This finding shows that guided inquiry-based learning applied in the experimental group is more effective on the academic achievement of students in terms of 'strength and energy' compared to the traditional teaching model applied in the control group. When the literature is examined, it is seen that there are many studies (Germann, Aram, & Burke, 1996; Marx, Blumenfeld, Krajcik, Fishman, Soloway, Geier, & Tal, 2004; Orcutt, 1997; Taşkoyan, 2008) with similar results. Bopegedera (2007), in his research in a guided inquiry-based chemistry laboratory, found that students' success in the subject increased. In this study, the activities carried out by the students in the classroom provided a better understanding of the subject and concepts. Since simple experimental equipments are used in the experiments used in the activities developed in the study, it can be easily applied in schools that do not have advanced science laboratories. However, there are also studies in the literature that do not support this result. In their study, Yıldırım and Berberoğlu (2012) compared the lessons based on guided inquiry and lecture method while teaching the 'force and motion' unit and found that there was no significant difference in improving the academic achievement of the students. Similarly,

Köksal (2008) and Serin (2009) found in their study that guided inquiry-based learning in the unit of 'force and motion' did not make a significant difference in the academic achievement of students. In the study, the effect of guided inquiry-based learning on students' science self-efficacy skills was investigated. As a result of the analysis, it was seen that the self-efficacy pre-test score of the control group students was higher than the pre-test score of the experimental group. When the pretest means of the experimental and control groups were compared, a significant difference was found in favor of the control group. When the pre-test scores of the experimental and control groups were taken under control and analyzed, a significant difference was found between the adjusted post-test scores of the groups in favor of the experimental group. According to this result, it can be said that the level of guided inquiry improves students' self-efficacy. In addition, this result can be deduced that the level of guided inquiry enables students to be more successful in doing science and to show persistence, stubbornness and patience when faced with adversity. Sağdıç (2018) examined the effects of guided inquiry-based learning on students' academic achievement, conceptual understanding, scientific process skills and attitudes towards the disciplines of Science-Technology-Engineering-Mathematics, and found that guided inquiry-based learning had an effect on students' scientific process skills. In his study, Ozan (2018) determined that there was a significant difference in favor of the experimental group among the achievements of students in guided inquiry-based science teaching, but there was no significant difference between attitude and self-efficacy scores. Feyzioğlu (2019), in his study examining the relationships between inquiry-based self-efficacy, achievement goal orientation, learning strategies and inquiry skills variables, concluded that inquiry-based learning does not improve students' self-efficacy skills. However, when the literature is examined, it is seen that self-efficacy is important in science teaching. According to the definition of Bandura (1994), the formation of self-efficacy in science teaching is a special case of structuring. Therefore, it is important to examine the role of self-efficacy that determines students' learning and effectiveness of teaching in science teaching (Duran, Ballone-Duran, Haney, & Beltyukova, 2009). A sense of self-efficacy develops when students begin to be successful. Based on the findings of the study results, it was concluded that there was a significant difference in the effectiveness of guided inquiry strategy in improving the academic performance and self-efficacy skills of students in a secondary school located in the southeast of Turkey, as those exposed to guided inquiry strategy performed better than the other group. Also, there was a significant difference between the groups exposed to guided inquiry and science curriculum (2018), as students taught science using guided inquiry performed better than those in the control group. Furthermore, the study concluded that guided inquiry was a better teaching strategy, as it was more effective in improving the academic performance and self-efficacy skills of secondary school students in the study area. Based on the findings of the study, it is recommended that the use of innovative teaching strategies such as guided inquiry teaching strategy should be encouraged as it was found to be useful in improving students' academic performance. Furthermore, further studies should be conducted to determine the effect of guided inquiry teaching strategy in teaching and learning of other subjects.

Research and Publication Ethics

In this study, all rules specified in the "Directive on Scientific Research and Publication Ethics of Higher Education Institutions" were followed. None of the actions specified under the second section of the Directive, "Actions Contrary to Scientific Research and Publication Ethics", have been carried out.

Disclosure Statements

1. Contribution rate statement of researchers: Author 100%.

2. No potential conflict of interest was reported by the author.

CRediT authorship contribution statement

Gamze KIRILMAZKAYA: Writing – review & editing, data collection, data analysis, methodology, conceptualization

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