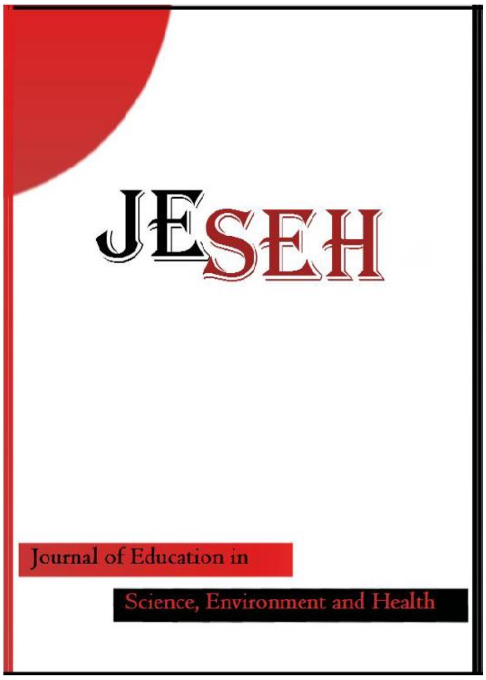

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Halil Ibrahim Akilli[1], Sevgi Kingir[2]
[1]Ministry of National Education
[2]Hacettepe University

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Abstract

This research aimed to investigate the impact of high-level teacher questioning on 6th grade students' science achievement, retention of learning and their attitudes toward science. A quasi-experimental pretest-posttest control group design was employed in this research. Participants consisted of 43 students enrolled in two intact 6th grade classes of a science teacher in a public elementary school. Two classes were assigned as either an experimental group or a control group randomly. Students in both groups were taught electricity concepts through student centered activities aligned with the national elementary school science curriculum. Difference between the two groups was the type of questions used by the teacher during the instruction. Background Questionnaire, Science Achievement Test, Attitude Scale and Structured Interview Form were used to collect data. ANCOVA results revealed a significant difference in science achievement and retention of learning across two groups, in favor of experimental group. However, independent t-test results demonstrated that students' attitudes toward science were not significantly different across the groups. Moreover, interview results supported the findings obtained from the achievement test.

Introduction

Innovations and developments in education and changing needs of society in the twenty-first century have influenced expected roles of the citizens of countries all over the world. This change demands having individuals who generate knowledge and transfer it to daily life, and are capable of using problem solving, critical thinking, decision-making, enterprising, empathy and communication skills (Ministry of National Education [MoNE], 2018). Instructional approaches used in science education are important in this context. One of the effective teaching approaches that helps to develop twenty-first century skills is inquiry-based learning.

Inquiry-based learning is a teaching-learning approach that emerged in the Western world in the 1950s. Being a process-oriented teaching pedagogy, it aims to teach how science is done as a process and procedure rather than teaching science as a body of knowledge. This approach has been emphasized as a main instructional approach to teach science to elementary school students in Turkish national science curriculum since 2013 (MoNE, 2013, 2018). Inquiry in the classroom varies depending on the relative amounts of student versus teacher control over an activity. There are essentially three forms of inquiry-based learning named as structured, guided and open inquiry. The more responsibility the learners take, the more open the inquiry. In a structured form of inquiry, students engage in investigations that are highly structured by teachers. In such an environment, learners follow prescribed procedure to test the questions provided by teachers. In an open form of inquiry, learners pose their own questions, design testing procedure, gather data, and make conclusions based on their own investigations (National Research Council, 2000).

Guided inquiry lies between structured and open inquiry. In this type of inquiry, investigation questions are provided by teachers, but the procedure is determined by learners. Students generally work in productive small groups while testing their questions; they make observations, record, analyze and interpret data. Each group summarizes their research and presents findings to the whole class. Throughout the process, students try to understand and discover new concepts. Teachers act as a guide and resource person in all steps of inquiry task. In order to stimulate learners to elaborate on their own views and draw conclusions based on their findings, teachers facilitate both small group and large group discussions (Martin, 2009).

Small group and whole class discussions naturally occur in effective inquiry-based classrooms. Some researchers in science education label these productive discussions as interactive scientific discussions (Chinn &

Anderson, 1998). Communication primarily occurs in the form of speech in the process of scientific discussion; students draw conclusions based on their investigations, revise their explanations considering others' feedback, provide evidence to support their claims and attempt to refute opposing viewpoints. Students' engagement in interactive scientific discussion increases their engagement and motivation to learn science and leads to conceptual change and scientific understanding (Chinn & Anderson, 1998; Kuhn, 1993).

Classroom Interactions

Mortimer and Scott (2003) proposed an analytical framework stemming from Vygotsky's theory of social development to analyze and describe student-to-student and teacher-to-student interactions in science classes. Classroom interactions could be in the form of either triadic or chain pattern. In a triadic pattern, classroom discourse proceeds in an order of Initiation-Response-Evaluation (IRE); where a dialogue is initiated by teachers with a question following students' responses and ended with teacher evaluation of the answers. Teacher's evaluation of a student's response limits other students' participation to express their own ideas. Chain pattern of discourse is in the sequence of Initiation-Response-Feedback-Response-Feedback (IRFRF). In this structure, teachers initiate the dialogue with a case or an interesting question, students respond to that question, teachers give feedback to students' responses as well as by asking for feedback from other students, without any evaluation. This sequence continues as response and feedback, which allows teachers to get different ideas from students.

Communicative approach is placed at the center of the analytical framework of Mortimer and Scott (2003). This approach concentrates on how diversity of ideas are developed through teacher-to-student interactions during lessons. The talk between teacher and students is categorized based on two dimensions. The first one is related to the degree of openness to different point of views, which ranges from authoritative to dialogic talk. Authoritative discourse does not acknowledge students' different ideas that are not aligned with the predetermined view. In contrast, dialogic discourse allows alternative thinking, students with different ideas are valued. The second dimension is related to the extent of participation of students, which ranges between non-interactive and interactive talk. An interactive classroom interaction involves engagement of more than one student, while a non-interactive one does not consider participation of others (Scott et al., 2006). Based on the two dimensions, communicative approach can be classified as follows: 1) interactive/dialogic, 2) non-interactive/dialogic, 3) interactive/authoritative and 4) non-interactive/authoritative (Scott et al., 2006; Scott & Mortimer, 2005). Teachers adopting interactive/authoritative communicative approach create an authoritarian classroom structure and allow participation of students for the purpose of supporting predetermined scientific view. The non-interactive/authoritative approach can be exemplified by expository teaching, where teachers deliver a predetermined view in the form of monologue. Role of teachers in an interactive/dialogic discourse is to value students' ideas, to take account of different point of views and to engage students in dialogues. In non-interactive/dialogic communicative approach, teachers explain different views to learners without allowing their involvement in the classroom discourse.

In an authoritative discourse, cognitive contributions of students are often excluded (Molinari et al., 2013; Molinari & Mameli, 2013). Teachers just focus on the scientific point of view and ignore alternative perspectives. Teachers can give information directly to the students, and evaluate the responses of the students such as right, wrong or incomplete. If the students' responses are not scientifically correct, teachers may not accept them or may refuse sharply (Edwards & Mercer, 1987; Lemke, 1990; McMahon, 2012). Although there is a student voice in this authoritative discourse, students' ideas that are not congruent with that of teachers are rejected. Teachers may summarize the main points of the lesson or classify the things based on their properties (Oh & Campbell, 2013; van Booven, 2015). In a classroom where dominant mode of discourse is dialogic, teachers encourage students to talk and debate with each other, to express their own thoughts freely, to listen to others, to develop scientific understandings, and to transfer newly acquired knowledge to new situations. Teachers moderate the discussion among the students. In a dialogic discourse, students' voices are heard in addition to teacher's voice. The important thing here is not only to hear the voices of the students but also emergence and consideration of different ideas (Mercer, 2010; France, 2019). Therefore, teachers may ask students to clarify or deepen their responses during the classroom talk (Pimentel & McNeill, 2013; Scott et al., 2006; van Zee & Minstrell, 1997). Teachers can also use focus moves to ensure students to monitor what is happening in the classroom (Christodoulou & Osborne, 2014; van Zee & Minstrell, 1997). In a dialogical discourse, teachers can encourage learners to take ownership for their learning (Crawford, 2000; Pimentel & McNeill, 2013). In addition, teachers can guide learners to assess, to critique, to judge and finally to legitimate their own and others' ideas and claims (Christodoulou & Osborne, 2014; van Zee & Minstrell, 1997). Moreover, teacher speech can lead students to present justified claims (Jadallah et al., 2011; McMahon, 2012; Soysal, 2019). For an effective dialogue in the classroom, a subject-matter topic that students are familiar with should be chosen and students need to be informed about providing evidence based on their investigations (Erduran et al., 2004). Previous experiences promote students' participation into classroom dialogues. If students connect new information into their existing cognitive structure, learning becomes meaningful and consistent. In addition, doing investigations in science classes facilitates students' development of reasoning skills and construction of evidence (Chen, 2020).

As highlighted above, teachers have an active role in a classroom interaction and take several actions that lead to interventions such as clarifying, elaborating, reviewing and sharing student ideas (Mortimer & Scott, 2003; Scott, 1998). A common form of teacher intervention is to support conceptual understanding by asking questions. Eliciting students' prior understandings and experiences via questioning helps to raise, maintain and resolve uncertainty which further leads to create and manage dialogic discourse (Chen, 2020). Through questioning, a teacher can introduce a new concept, concentrate on student response, mark key concepts, check students' understanding, make ideas available to whole class, and summarize what has been covered.

Teacher Questioning

Questioning is an integral part of educational process. Teacher questions are frequently used in science classrooms. When teachers ask the right questions for the right purpose and at the right time, they can help students to understand science phenomena (Lemke, 1990; Mortimer & Scott, 2003; Scott et al., 2006). Effective teacher questioning also leads to scientific inquiry and reasoning. Questions play a crucial role in explaining and summarizing ideas, proposing claims, and backing up those claims with evidence (Chin, 2004; Chin & Osborne, 2008).

High-level teacher questioning has a great impact on shaping discourse that occur in a classroom (Chin, 2007; France, 2019). Quality rather than quantity of teacher questions is effective in promoting student learning (Gall, 1970). Asking higher cognitive level questions facilitates students' connection of new information with their existing knowledge and accordingly increases their achievement (Çimer, 2007). To build a dialogic interaction, teachers need to ask questions that allow multiple potential student responses. The important thing is that questions asked by teachers should not have a single correct answer. It was reported that students could express their thoughts using compound and complex sentences with vocabulary specific to content when teachers ask open-ended questions that encourage student thinking (Morris & Chi 2020; Oliveira, 2010). Using multiple representations when asking questions facilitates students' construction of abstract knowledge in their minds (Chen, 2020). Moreover, studies have demonstrated that science classes initiated with open-ended teacher questions and sustained with student dialogues improve student achievement (Lee & Kinzie, 2012).

Studies demonstrated that students do not ask too many questions spontaneously when teachers do not ask any questions (Chin & Osborne, 2008; Aguiar et al., 2010). As teachers ask low-level questions, number of students' questions decreases (van Zee et al., 2001). Conversely, when teachers ask high-level questions, students' questions increase not only in quantity but also in quality (Chen et al., 2017). The quality rather than the quantity of students' questions was found associated with their achievement in their classes (Harper et al., 2003). These findings imply that it is crucial for teachers to adopt high-level questioning in order to build dialogic learning where learners develop high-level questions (Günel et al., 2012).

As stated above, productive teacher questioning practices has the potential of building an effective classroom environment where learners are encouraged to develop positive attitudes toward science. Attitude toward science is a significant affective construct described as the extent to which an individual likes or dislikes science (Oliver & Simpson, 1988). Students' feelings regarding classroom activities contribute to their learning and attitudes toward science (Salta & Tzougraki, 2004; Talton & Simpson, 1987). Studies have demonstrated that students' positive attitudes could be improved by using effective science instruction (Artino, 2012). Existing literature generally showed positive associations of attitudes toward science with science achievement (e.g., Liou et al., 2020).

Previous literature consistently demonstrate that communicative approaches adopted in science classes are predominantly authoritative (Ateş et al., 2016; Kaya et al., 2016; Mercer et al., 2009; Ryder & Leach, 2006). One reason of preference of authoritative approach rather than dialogic approach is its features of convenience and easy to use (Mercer et al., 2009). Another reason is related to lack of time because dialogic discourse requires much time compared to authoritative discourse (Uçak & Bağ, 2018). In order to have science classes aligned with the principles of inquiry-based teaching approach stated in national science curriculum (MoNE, 2018), teachers need to organize and maintain a classroom environment where dialogic communicative approach is adopted (Mortimer & Scott, 2003) and new social norms are constructed (Özmantar et al., 2009). However, studies reveal that teachers are not sufficient in creating dialogic interaction in science classes (Ateş et al., 2016; Kaya et al., 2016). Teacher questioning is a significant agent that leads to dialogic learning environment (Chen et al., 2017). Early studies mainly aimed to analyze and determine types of classroom discourse (Ateş et al., 2016; Kaya et al., 2016; Ulu, 2017). Different from those studies, this study adopted quantitative research design to investigate the impact of high-level teacher questioning on elementary school students' science achievement and retention of learning in electricity unit. Learning tasks that are fun, interactive and enjoyable help to develop positive attitudes toward science (Koballa & Glynn, 2004). For this reason, the impact of high-level teacher questioning on students' attitudes toward science was also investigated in this context. In addition, students' views about the intervention used in experimental group was elicited. Specifically, teacher questions that aim to initiate and maintain dialogic discourse were used as an intervention. This study has the potential of serving as a guide for teachers on using high-level questioning that encourage dialogic interaction and learning in science classes. Accordingly, following research questions were proposed:

1. What is the impact of high-level teacher questioning on 6th grade students' science achievement and retention of learning in electricity unit?
2. What is the impact of high-level teacher questioning on 6th grade students' attitudes toward science?
3. What are the views of 6th grade students regarding the implementation of the high-level teacher questioning?

Method

Design of the Study

This study utilized a quasi-experimental pretest-posttest control group design in order to investigate the impact of high-level teacher questioning on students' science achievement, retention of learning and attitudes toward science. Quasi-experimental design is frequently used in educational research when random assignment is not possible or practical (Fraenkel et al., 2012). The dependent variables were scores on Science Achievement Test and Attitude Scale while the independent variable was teacher questioning.

Participants

Participants included 43 students enrolled in two 6th grade classes of a public elementary school in a city located in the central region of Turkey. Convenience sampling technique was utilized for selecting participants in this study. Convenience sampling can be used in cases when it is difficult to choose a random or systematic non-random sample. In this type of sampling, a certain group of people are chosen because of their availability and easy access (Fraenkel et al., 2012). All taught by the same teacher, one class was assigned as experimental group (13 boys and 9 girls) and the other class as control group randomly (12 boys and 9 girls). Students' ages were between 12 and 13 years old.

Data Collection

Data were gathered using Background Questionnaire, Science Achievement Test, Attitude Scale and Structured Interview Form. Details about these tools were provided below.

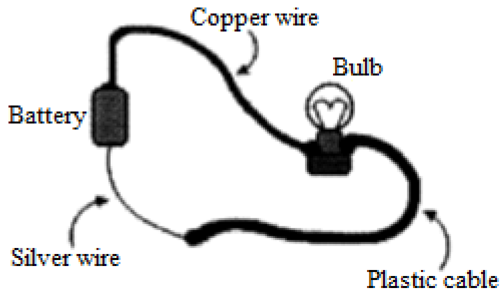
Background Questionnaire

This questionnaire was administered to the students to provide information about their background characteristics, namely, age, gender, previous science grade, and educational level of parents. Level of education completed by parents were asked in multiple-choice format with following options: 1- primary school, 2- elementary school, 3- high school, 4- university and 5- postgraduate degree.

Science Achievement Test

This test was constructed by the researchers to assess students' achievement in electricity unit. In the first stage, an item pool consisting of 34 questions was generated considering the objectives of the 6th grade electricity unit stated in the national elementary school science curriculum (MoNE, 2013). Researchers benefited from textbooks and nationwide student selection exams for high schools when writing test items. For content validity, a table of specification, that include objectives of the electricity unit and items for each objective, was prepared by the researchers. Questions were also considered to be at different cognitive levels of Bloom's taxonomy. Then, an expert in science education was consulted to render judgment on the appropriateness, adequacy and suitability of the science achievement test using the table of specification. This test was also examined by a Turkish language teacher and an elementary school science teacher for face validity. Based on comments provided by the experts, some items were revised, some were discarded. In all, 20 items were included in the final form of the test. A pilot study was conducted with 20-item science achievement test to assess its reliability. Reliability of the instrument was computed as .84 using Kuder-Richardson (KR-20) formula.

Final version of science achievement test included 20 multiple-choice questions in the electricity unit (See Figure 1 for sample item). Items were related to conductive and insulating materials, electrical resistance and factors affecting electrical resistance. Each item included one correct answer and three distracters. One point was given for each correct response; zero point was given for non-response or a wrong response. Total score of the test ranged between 0 and 20. Science Achievement Test was used in the two groups as a pretest before the treatment, a posttest after the treatment, and a retention test four weeks after the posttest. All tests were administered by the teacher in a class hour.



Which of the following should be done to light up the bulb in the above electric circuit?

A) Copper wire should be used instead of silver wire.
B) Plastic cable should be used instead of copper wire.
C) Silver wire should be used instead of plastic cable.
D) Silver wire should be removed from the circuit.

Figure 1. A sample item used in Science Achievement Test

Attitude Scale

Students' attitudes toward science were assessed utilizing Attitude Scale developed by Akıllı (2008). The scale consists of 28 items (e.g., "I like science classes") measured on a 5-point Likert type scale ranged from 1 = fully disagree to 5 = fully agree. It includes both positively and negatively worded statements. After reverse coding of negatively worded items, total score was calculated. The minimum score of this scale was 28; while the maximum was 140. Higher scores indicate positive attitudes of the students while lower scores express negative attitudes toward science. A reliability coefficient of .85 was obtained for the original scale while it was computed as .86 for the present study. This scale was administered to both groups before and after the instruction and took approximately 15 min.

Structured Interview Form

In order to support the experimental data, a structured interview was constructed by the researchers and conducted to the experimental group students. A researcher in science education was consulted to examine the first draft of the interview form which included five open-ended questions. Interview form was revised and re-organized by combining similar questions, and the number of open-ended questions was reduced to three, based on the comments of the expert. The reason behind the use of a structured interview form was to elicit students' opinions regarding the instruction guided by high-level teacher questioning in order to support findings obtained from self-report instruments. Through interviews, students were asked to compare their science classes in electricity unit with that of in previous units (e.g., How do you compare your science classes in electricity unit with that of in previous units?). Students were also asked to describe any changes that they observed in themselves and their teacher throughout the implementation. Face-to-face interviews were conducted by the first author with five volunteering students. All interviews were audio recorded after informed consent was obtained. The interviews lasted approximately 15 minutes.

Procedure

This study lasted four weeks with four 45-min sessions per week. Electricity concepts were instructed as part of the regular science curriculum by devoting equal amount of instructional time for both groups. Students in both groups were instructed using student centered activities aligned with the national elementary school science curriculum. The difference across two groups was teacher questioning strategy during the instruction. For internal validity, both groups were instructed by one of the researchers, who is also a science teacher in the elementary school selected for this study. The teacher is a PhD in science education and took several PhD courses (e.g., discourse analysis). He is also experienced in teaching science for 15 years. In order to minimize implementation threat to internal validity, lessons, especially classroom interactions were video-recorded by the teacher in both groups, after obtaining necessary permissions and consent forms. Prior to the instruction, the Science Achievement Test and Attitude Scale were administered to the students in the two groups. Following the instruction, the same instruments were given to both groups. At the end of the implementation period, face-to-face structured interviews were held with five volunteering students in the experimental group in order to elicit students' opinions regarding the instruction guided by high-level teacher questioning. One month later, Science Achievement Test was re-administered to all of the students as a retention test.

Implementation in Control Group

Lesson plans were developed considering the instructional approach specified in national elementary school science curriculum. Students engaged in experiments and activities related to the conductive and insulating materials, electrical resistance and factors affecting electrical resistance. In choosing classroom activities, the teacher used textbook, smart board, and Education Information Network which is developed by Turkish Ministry of Education. Students conducted experiments in the laboratory after the teacher reminded students of the laboratory safety rules. During the laboratory activity, students recorded their observations and then they interpreted their data. Students individually filled out a laboratory report which included following sections: Purpose, materials, procedure, observations and data, and conclusion. Students were also asked to respond questions both included in the textbook and provided on the smart board. The teacher mostly asked knowledge and procedural questions which require students to give short answers without leading to any further dialogic interaction (e.g., What are conductors? What materials are generally used as conductors?). As in his previous classes, the teacher also did not use effective talk moves in the classroom. Therefore, in the control group, dialogic interaction did not occur.

Implementation in Experimental Group

The instructional process followed in both groups was the same except teacher questioning. In the experimental group, the teacher asked questions that allow discussion and debate in the classroom. When students were asked to respond questions included in their textbook or shown on the smart board, they were also asked to provide reason for their answer in oral or written format. Types of the questions used in the experimental group allowed students' participation in learning tasks and helped to create dialogic interaction in the classroom environment. The purposes of the questioning are shown in Table 1.

Table 1. Purpose of questioning along with samples

Purpose of questioning	*Sample question*
require students to give reasons for their responses	Why do you think like that? How do you know?
make students to provide evidence for their claims	Do you have data that support what you said? What is your evidence?
make students to convince others	How do you convince your classmate?
to clarify students' responses	I could not understand, could you repeat and explain a bit more?
to facilitate student-to-student interaction	Does it make sense to you? What do you think about your friend's idea?

In order to illustrate how teacher questions facilitated dialogic talk, an excerpt of classroom interaction related to the conductive and insulating materials is given in Table 2. This table indicate that teacher questions helped to create a discussion environment, which can be defined as interactive/dialogic interaction. The teacher attempted to get student response in accordance with chain pattern. Students were encouraged to provide reasons for their answers, and thereby it was aimed to make students construct knowledge in their minds rather than simple memorization and recall of facts and information. Although students had difficulty in adapting to such dialogues in the classroom at the beginning, they got used to it in time.

Table 2. An excerpt of classroom interaction drawn from experimental group

Line	Person	Speech
1	Teacher	What are the differences between the properties of conductive and insulating materials? What property does it take for a substance to be conductive?
2	Student 1	It might be related to density of materials.
3	Teacher	How?
4	Student 1	For example, gold is a good conductor. Its density is also high.
5	Teacher	So you mean that plastic has lower density? How do you know that the density of gold is more than that of plastic?
6	Student1	We learned in our lesson (We did its experiment).
7	Teacher	Well, so the amount of it (gold) in the same volume was heavier, right? So, what kind of property can the substance of high density have so that it transmits the electric current more?
8	Student1	Since its particles are closer together, it is easier to transmit electricity.
9	Teacher	So is it easier for it (electricity) to jump from one side to another side?
10	Student 2	Sir, the number of particles per unit volume is equal to density.
11	Teacher	Density is the number of particles per unit volume… Well, as your friend said … So if you take equal volumes of gold and plastic and weigh them, the gold weighs more, doesn't it? As your friend said, the mass per unit volume is higher. Does anyone want to add anything else? Any other thoughts?... So, because the particles are close to each other, you mean that the transmission of electricity is easier?
12	Students	Yes…
13	Teacher	Does anyone want to summarize what your friends are saying? Is there anyone who wants to compile and gather (ideas), and compile and say it stems from …?

Data Analysis

Quantitative data were analyzed using parametric tests with IBM 21 SPSS software because skewness and kurtosis values of the dependent variables ranged between -2 and +2 (Can, 2017). Pretest scores on Science Achievement Test and Attitude Scale were analyzed through independent t-test. The groups were compared on the posttest mean scores of Science Achievement Test using Analysis of Covariance (ANCOVA) by controlling the pretest scores. Posttest scores of the Attitude Scale and retention test scores of the Science Achievement Test were analyzed via independent t-test. The statistical decision was made using a significance value of .05 ($p < .05$). For independent t-test analysis, Cohen's *d* index was computed to find out the size of the difference across the groups. Effect size was interpreted based on the criteria suggested by Cohen (1992) as small ($.2 < d < .5$), medium ($.5 < d < .8$) and large ($d > .8$). For ANCOVA, partial eta squared value was interpreted for effect size measure. Green and Salkind (2014) suggested values for small ($.01 < \eta^2 < .06$), medium ($.06 < \eta^2 < .14$), and large ($\eta^2 > .14$) effect sizes. Meanwhile, the data obtained from structured interviews were analyzed descriptively. Audio recordings obtained from interviews were transcribed into text and the findings were presented based on the questions used in the interviews. Direct quotations were also used to highlight the students' opinions. The interviewees were named from Student 1 to Student 5 due to ethical concerns.

Results

Findings obtained from the administration of Background Questionnaire, Science Achievement Test and Attitude Scale were presented in this section. The findings of the student interviews were also reported.

Findings of the Background Questionnaire

Independent t-test results comparing students' scores on background characteristics across two groups were depicted in Table 3.

Table 3. Independent t-test results on students' background characteristics

Dependent Variable	Group	n	Mean	SD	t	df	p
Previous science grade	Experimental	22	66.95	21.91	1.23	41	.225
	Control	21	59.86	15.44			
Mother education level	Experimental	22	2.00	.98	-.97	41	.338
	Control	21	2.29	.96			
Father education level	Experimental	22	3.09	1.23	.67	41	.510
	Control	21	2.86	1.06			

As shown in Table 3, prior to the treatment, experimental group held higher mean scores than the control group with respect to previous science grade. Independent t-test analysis revealed that mean scores of previous science grade were not significantly different across two groups, $p > .05$. Table 3 also shows that students' parent education level was generally lower than high school. Education level of mothers was found lower than that of fathers. The difference in parent education level was not significant between the two groups, $p > .05$. From these results, it may be interpreted that both groups were equal prior to the instructional treatment in terms of students' background characteristics.

Findings of the Science Achievement Test

Science Achievement Test was administered as a pretest before the treatment, a posttest after the treatment and a retention test one month after the posttest. Independent t-test results comparing the two groups with respect to pretest scores on Science Achievement Test were depicted in Table 4.

Table 4. Independent t-test results on pre-test scores of science achievement

Group	*n*	*Mean*	*SD*	*t*	*df*	*p*
Experimental	22	9.55	3.42	2.06	41	.046
Control	21	7.62	2.64			

As shown in Table 4, experimental group held higher mean scores than the control group with respect to science achievement, prior to the treatment. Independent t-test analysis revealed that difference in the mean scores of science achievement was significantly different across two groups, $p < .05$. This result demonstrated that the two groups were not equal prior to the instructional treatment in terms of science achievement. Therefore, Analysis of Covariance (ANCOVA) was run for analyzing students' posttest scores on Science Achievement Test in order to control the effect of the pretest scores (Table 5).

Table 5. ANCOVA results on the posttest mean scores of science achievement across two groups using pretest mean scores as a covariate

Source	Sum of Squares	df	Mean Square	F	p	Partial eta squared
Pretest	226.46	1	226.46	18.26	.000	.31
Group	67.87	1	67.87	5.47	.024	.12
Error	495.99	40	12.40			
Total	7611.00	43				

Table 5 shows that experimental group students ($n = 22$, $Mean = 14.50$, $SD = 4.62$) significantly outperformed those in the control group ($n = 21$, $Mean = 10.38$, $SD = 3.71$) on posttest scores of science achievement, $p < .05$. Partial eta squared value was computed as .12, indicating a medium effect size. This finding suggests that observed difference was not only statistically significant but also practically meaningful, which also means that high-level teacher questioning really does have an effect on science achievement. One month after the posttest, Science Achievement Test was administered as a retention test. Table 6 displays independent t-test findings across the groups with respect to retention of learning.

Table 6. Independent t-test results on retention test scores of science achievement

Group	*n*	*Mean*	*SD*	*t*	*df*	*p*
Experimental	21	14.71	4.27	2.66	40	.011
Control	21	11.43	3.71			

Table 6 demonstrates both a statistically significant and practically important difference in students' retention test scores of science achievement in the favor of experimental group (p < .05; Cohen's d = .82). This finding also reveals the long-term effects of high-level teacher questioning on students' science achievement.

Findings of the Attitude Scale

Independent t-test results comparing the two groups in attitude toward science were depicted in Table 7.

Table 7. Independent t-test results on attitude toward science

Dependent Variable	Group	n	Mean	SD	t	df	p
Pretest	Experimental	22	97.73	12.95	.60	40	.55
	Control	20	95.15	14.73			
Posttest	Experimental	22	101.45	13.18	.93	40	.358
	Control	20	98.45	7.07			

As shown in Table 7, students in the experimental group held higher mean scores in attitude toward science than those in the control group both before and after the implementation. Independent t-test results demonstrated that difference in both pretest and posttest mean scores of attitude toward science were not significantly different across two groups, p > .05.

Findings of the Student Interviews

Interview results revealed that students mainly viewed the difference between the instructional approach followed in electricity unit and the instruction used in previous units as teacher questioning. Students thought that the teacher asked thought-provoking questions while teaching electricity unit. They also stated that the teacher gave feedback to their responses without evaluating them as correct or false, and directly giving the correct response. For example, a student stated his ideas as follows; "The teacher was asking us questions. He did not say the answer even if we did not give the correct answer".

Based on the students' views, the teacher also extended and elaborated students' responses. The teacher gave value to students' ideas; that is, he tried to take opinions of everyone in the classroom and asked for different points of view. For example, a student responded as follows: "(Our teacher) was taking opinions and views of whole class, asking for any other answer". Students expressed that the teacher questioned why they thought like that, following their responses. Students further claimed that they understood electricity unit very well because of the teacher's 'why' questions followed by 'what' questions. For instance, a student stated her views as, "...Our teacher asked us to answer the questions by providing reasons. Therefore, I understood the subject better.".

Interview results further indicated a positive shift in students' attitudes toward science. Interviewees viewed science classes as entertaining, not boring. They expressed that instructional approach used in the electricity unit caused them some positive changes, such as learning better, talking much and getting higher grades. For instance, an interviewee expressed her opinions as, "I think, it (science class) was different from other (previous) units, simple and fun. I'd like to have science classes in a way that is used in the electricity unit. Because, for me, it's fun in this way". Moreover, almost all of the interviewees preferred to have further science classes as in the electricity unit.

Discussion

This research examined the impact of high-level teacher questioning on science achievement, retention of learning, and attitudes toward science in electricity unit at elementary school level. The findings revealed significant differences both in posttest and retention test scores of science achievement across the groups in the favor of the experimental group, revealing a large effect size. This finding implies that as teachers ask questions that aim to initiate and maintain dialogic discourse, their students' science achievement increases and this impact is persistent over time. This result is aligned to the previous research revealing positive impacts of effective questioning on learning and achievement (Chin, 2004; Chin & Osborne, 2008; Güveli, 2019). Questions asked in the classroom serve as a key factor in learners' elaboration of their own ideas, construction of new claims, and providing evidence to support those claims. High-level teacher questioning facilitates students' construction of their own knowledge in their minds and long-term retention of knowledge. Teachers have the main responsibility in creating a learning environment that allows students to ask questions and transforming the classroom interaction from authoritative to dialogic. However, studies consistently reveal that most teachers do not use effective questioning strategies in their classrooms (Zhu & Edwards, 2019; Cumhur & Güven, 2018). Asking high-level and follow-up questions activate students' thinking processes, which in turn lead students to participate in classes and learn the concepts better (Günel et al., 2012; Lim et al., 2020). Asking high-level questions stimulates recall of prior knowledge and facilitates students' connection between the concepts (Harper et al., 2003, Çimer, 2007). As the level of the teacher questioning increases, the students tend to think critically considering multiple perspectives and give a longer and more in-depth response rather than just "yes" or "no" (Aziza, 2018; Schindler et al., 2018).

Meanwhile, the findings of the current study demonstrated a non-significant difference in attitudes toward science across two groups. This study is similar to that of Uyanık (2016) who found a significant difference in academic achievement and retention but not a significant difference in attitude of 4th grade students in a research testing the effect of learning cycle method in primary science. The reason of having a non-significant group difference in students' attitudes toward science might be associated with relatively short period of the study. Although the teacher had an experience of 15 years, his experience in using high-level questioning in science classes was limited to six months at the time of the study. Studies consistently have revealed that at least 18 months is required for significant changes in teachers' questioning pedagogy (Chen et al., 2017; Martin & Hand, 2009). Moreover, four-week experimental procedure might be limited for development in students' attitudes toward science. This finding is congruent with the existing research indicating that change in attitude requires time to occur (Ferkany et al., 2014; Kapici et al., 2020; Uyanık, 2016). Moreover, using self-report instrument for measuring attitudes toward science might be limited in assessing the impact of the treatment because interview findings of the current research demonstrated positive attitudes toward science in the experimental group. Similar long-term studies using in-depth qualitative data might be useful in enhancing our understanding regarding the impact of high-level questioning on students' attitudes toward science.

Interviews also elicited students' opinions about the intervention used in experimental group. Students thought that teacher questioning process which include thought provoking questions, non-evaluation of responses, extending and elaborating responses, and valuing students' ideas created an entertaining learning environment and contributed to their understanding of science concepts. Such findings suggest that effective teacher questioning has positive impacts on students' learning outcomes. Results of the interviews are also congruent with the results of the current research indicating the impact of high-level teacher questioning on students' science achievement and retention of learning.

Conclusion and Recommendations

This study highlighted the role of effective teacher questioning in creating dialogic classroom interaction and thereby increasing students' science achievement and retention of learning. Dialogic talk is an important aspect of inquiry-based teaching approach which has been emphasized in school science curricula of many countries including Turkey (MoNE, 2013, 2018). However, studies consistently revealed that teachers generally adopted authoritative approach in science classes (Ateş et al., 2016; Kaya et al., 2016; Mercer et al., 2009; Ryder & Leach, 2006). This study can guide teachers on how they can create dialogic interaction through effective questioning, and in turn how they can improve their instructional practices. If teachers ask high-level questions to students, they become more effective and efficient in the classroom, sustain dialogues with their students and feel more confident in teaching (Forster et al., 2019; Karademir et al., 2019; Rodriguez & Bonner, 2018).

In interpreting the results of this research, it is worth to consider following limitations. First, duration of the research was limited to four weeks. There were significant improvements in students' science achievement and retention of learning. However, students' attitudes toward science was not significantly improved. Similar long-term studies might be undertaken to examine the impact of teacher questioning on students' attitudes toward science. Another limitation of the research is related to the sample size and sample selection procedure. This study comprised a relatively small sample size and utilized convenience sampling which limits the generalizability of the findings. Therefore, similar studies can be conducted on larger samples representing the population. Future studies with different levels of students in a variety of context and investigating the effect of student questioning on different learning outcomes are also recommended.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

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Author Information

Halil Ibrahim Akilli
Ministry of National Education
Kizilcahamam, Ankara/Turkey
Contact e-mail: *halil.akilli@hacettepe.edu.tr*
ORCID iD: https://orcid.org/0000-0002-0232-0273

Sevgi Kingir
Hacettepe University
Department of Primary Education
Beytepe, Ankara, Turkey
ORCID iD: https://orcid.org/0000-0003-1848-4392