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Tuğba Geçgil
Yıldız Technical University, Turkiye

Hakan Akçay
Boğaziçi University, Turkiye

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Investigating the Effects of Different Model Based Inquiries on Students' Science Achievement, Scientific Process Skills and Motivation

Tuğba Geçgil, Hakan Akçay

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Abstract

In this research, the effects of using Model-Based and Argumentation-Supported Model-Based Inquiry methods on 6th-grade middle school students' knowledge, scientific process skills, and motivation regarding the subject of sound and its properties were examined according to the current curriculum. A total of 77 students attending a state school participated in the study that employed a mixed research design. In the semi-experimental study, two experimental groups and one control group were used. Lessons were taught according to the model-based inquiry method supported by argumentation in the first experimental group, according to the model-based inquiry method in the second experimental group, and according to the current curriculum in the control group. In the research, achievement tests, scientific process skills tests, and motivation scales were administered as pre-tests and post-tests for data collection. The obtained data were analyzed using One-Way Analysis of Covariance (ANCOVA). According to the obtained results, it has been determined that the Model-Based and Argumentation-Supported Model-Based Inquiry methods significantly differ from the current curriculum in terms of student achievement and motivation. Furthermore, it has been observed that the Argumentation-Supported Model-Based Inquiry method is more effective than the Model-Based Inquiry method in enhancing students' development of scientific process skills.

Introduction

Throughout history, the changing world has brought about many transformations and continues to do so. These transformations occurring in society bring along different needs. When individuals are expected to respond to the needs of society as a member of the society they live in, significant changes are also expected in the field of education, which is the process of helping individuals acquire desired behaviors. The field of natural sciences holds great importance in the social and economic development of countries (Ünal, Coştu & Karataş, 2004). According to Osborne (2007), science cannot be described separately from technology (in curricula and teaching). Countries aspiring to progress in science and technology, produce technology, and compete in the global market must prioritize science education to be at the forefront in this competitive environment (Çepni & Çil, 2009). Therefore, when examining national and international program development efforts in the field of natural sciences, it becomes evident that countries continuously engage in program evaluation and updating activities in line with their needs and policies (Deboer, 1996).

Creating effective discussions among students, assigning them the task of evaluating their peers' viewpoints, assisting students in generating ideas and practices for problem-solving, and promoting the civil discourse types required by democracy are of critical importance (Amirbekova, Kussaiyn, & Narbaev, 2022; Ozturk, 2023; Ozturk & Susuz, 2023; Owens, Sadler & Zeidler, 2017). Through science education, individuals can acquire new ideas and research skills that contribute to their self-regulation, personal satisfaction, and social responsibility. Science education should motivate individuals to think and take action. Additionally, it should create awareness about richly interconnected knowledge, intellectual skills that allow individuals to work with what is known, and texts in which this knowledge and skills are applied (Deboer, 1996). Activities that enhance individuals' knowledge and reasoning skills should be conducted in science education (Osborne, 2007).

The Model-Based Inquiry (MBI) method can be applied as the most suitable and appropriate teaching method that aligns with current curriculum and the principles outlined above. In the MBI method, students engage in research, inquire, use argumentation methods, and update their models, all while communicating collaboratively with their peers. MBI is a newly developed educational design that enables students to interact with scientific practices and concepts such as modeling, explanation, and reasoning while attempting to explain natural phenomena that support the unit being covered. MBI is designed in accordance with the Next Generation Science Standards (NGSS, 2013) to engage students in comprehensive learning experiences. NGSS argues that models should not be used solely as tools for students to explain concepts; instead, students should actively participate in the process of designing and constructing their own models, which they use either to explain a concept or, more importantly, to make predictions (NGSS, 2013).

Stewart et al. (2005) defines the Scientific Model as a set of ideas that describe a natural process. As a type of scientific explanation, models serve as a bridge between theories and the real world (Lehrer & Schauble, 2010). Models serve the purpose of being tools for thinking, making predictions, and making sense of experiences. Classroom modeling application refers to a student or group of students creating models as representations of events or systems and using these models to explain or predict events (NRC, 2012).

There are various ways to classify models. When looking at the classifications, models can be categorized as internal mental models or external conceptual models (expressed models) in the most general sense (Gobert & Buckley, 2000). McBroom (2011) states that the world we live in, the world we learn (conceptual models), and the world we perceive (mental models) are in constant interaction with each other. According to Vosniadou (1994), mental models are students' individual interpretations about concepts. A mental model is the abstraction of a specific system or phenomenon, and therefore, it is not a one-to-one representation of physical reality (Halloun, 2007). According to Khan (2007), mental modeling is not a one-to-one representation of the external world. On the other hand, conceptual models are the external, coherent representations of mental models (Greca & Moreira, 2000). Gobert & Buckley (2000) refer to these as expressed models. Since mental models cannot be directly assessed, it is necessary to build expressed models for the evaluation and communication of mental models. An expressed model is the external presentation of the mental model created by the owner of the mental model through drawings, verbal explanations, or other model construction forms (Gilbert and Ireton, 2003). According to Greca & Moreira (2000), conceptual models (expressed models) are typically external presentations created by researchers, teachers, and engineers to facilitate the understanding or teaching of systems and situations in the world.

Modeling can be a powerful exercise for students to present their thoughts (Windschitl, Thompson & Braaten, 2008a) and can be a productive tool for explaining and predicting events (Schwarz et al., 2009). However, it is often a misunderstood subject; modeling is more than just creating a scaled model or drawing a diagram. Planned learning environments should make use of modeling practices (Schwarz et al., 2009). Modeling is a central practice in the generation and evaluation of scientific knowledge (Nersessian, 2008). It has been thought that through modeling, students' work could be parallel to the work done by scientists (Passmore et al., 2009; Windschitl, Thompson & Braaten, 2008b). As a learning approach, MBI stems from the view that science focuses on developing explanatory models and that students should build understanding through a process similar to how scientists make sense of the natural world (Clement, 2000). MBI is an iterative and cyclical methodological approach in science education that involves the development, use, evaluation, and revision of models to explain patterns in collected data or real-world phenomena (Passmore et al., 2009).

When compared to some inquiry-based teaching approaches, the Model-Based Inquiry (MBI) method offers several key similarities and differences. Previous inquiry-based approaches, unlike the MBI method, tend to emphasize experimental research more by reducing scientific practice to a single procedure. In addition, there are learning methods where students are engaged in an experiment or activity related to a scientific problem or question, allowing them to explore what they know or do not know about the question. Along with MBI, these approaches share similar goals related to student-centered learning. MBI not only provides a structured, productive, student-centered classroom environment but also offers opportunities for rich collaboration (Baze & Gray, 2018). They emphasize the active construction of knowledge by students and all start with students' prior knowledge. The key difference between the MBI method and others lies in its engagement in activities commonly used in science, such as modeling and discussion. The model-based approach allows for the separation of argumentation units based on evaluated models; therefore, models can serve as sufficient reference points that enable the structural and content-related description of arguments (Boettcher & Meisert, 2011). Researchers assume that involving students in discussions in model-based learning encourages them to engage in thinking, acting, and speaking like scientists (Praisri & Faikhamta, 2020).

Although there have been several studies drawing attention to the relationship between model-based inquiry and argumentation (Mendonça & Justi, 2013; Passmore & Svoboda, 2012; Boettcher & Meisert, 2011), it has been observed that there are limited studies in the literature that address both model-based inquiry and argumentation processes together (Evogorou et al., 2020; Kara, 2019; Gülbaş, 2019). Osborne et al. (2004) emphasized that argumentation is both an individual and social activity, stating that it can be seen as an individual activity through thinking and writing, and as a social activity because it is discussed within a specific community. A scientific argument refers to dialogic conversations in which participants put forth claims based on evidence, and these claims are either accepted or refuted within the group. The best argument is formed through the presentation of multiple perspectives and structured discussions that lead to a consensus in the classroom (Erduran, Simon & Osborne, 2004). Toulmin has examined argumentation in terms of its constituent elements, and an argument consists of six elements. The first three elements (data, claim, and warrant) form the foundation of an argument, while the other three (backing, rebuttals, and qualifiers) are auxiliary components. While the first three elements are necessary for constructing an argument, the other elements contribute to the validity of the argument (Erduran et al., 2004).

The abstract nature of the natural sciences has increased the use of models in science class-rooms (Çökelez, 2015; Güneş, Gülçiçek & Bağcı, 2004). The results obtained from the studies suggest the implementation of modeling in different grade levels and subject areas (Çoban et al., 2016). Various studies have been conducted on the topic of sound in science classes (Küçüközer, 2009). However, no research has been found on the application of the MBI method in the context of the topic of sound. The majority of model-based research in science education focuses on studies that examine mental models, conceptual learning, and their effects on the nature of science (Vosniadou et al., 2004; Bilgin & Geban, 2001; Batı & Kaptan, 2017; Gülbaş, 2019; Praisri & Faikhamta, 2020). Limited studies have been found that investigate students' scientific process skills and motivation towards the course (Sarıkaya et al., 2004).

This research aims to investigate the effects of the Model-Based Inquiry (MBI) and Argumentation-Supported Model-Based Inquiry methods on 6th-grade middle school students' achievement, scientific process skills, and motivation regarding the subject of sound and its properties in accordance with the existing curriculum. To achieve this aim, the following research questions were addressed:

1. How does the use of the Model-Based Inquiry (MBI) and Argumentation Supported Model-Based Inquiry methods regarding the subject of sound and its properties affect the science achievements of 6th-grade middle school students according to the existing curriculum?
2. How does the use of the Model-Based Inquiry (MBI) and Argumentation Supported Model-Based Inquiry methods regarding the subject of sound and its properties affect the scientific process skills of 6th-grade middle school students according to the existing curriculum?
3. How does the use of the Model-Based Inquiry (MBI) and Argumentation Supported Model-Based Inquiry methods regarding the subject of sound and its properties affect the motivation of 6th-grade middle school students according to the existing curriculum?

Method

This research used a quantitative research paradigm based on a quasi-experimental design with a pre-test post-test control group (Karasar, 2009). The study covers the teaching process of the "Sound and its Properties" unit for 6th-grade middle school students. In the first experimental group, the Argumentation Supported Model-Based Inquiry (MBI) method was used. In the second experimental group, only the MBI method was used, and in the control group, traditional methods in line with the curriculum were used for teaching.

Sample

In the study, study groups were determined through accessible sampling. In this context, three classes from a state school in Bursa, Turkey, were selected, with two of them being experimental groups and one being a control group. A total of 77 students from three different 6th-grade classes participated in the study. The gender distribution of the students who participated in the study is shown in Table 1.

Table 1. Mean and Adjusted Mean Scores for the Achievement Test

Group	Female	Male	Total
Control	12	14	26
Experimental-1	14	11	25
Experimental-2	12	14	26

During the study process, the lessons in the experimental group were conducted by the researcher, while the lessons in the control group were conducted by another teacher.

Data Collection Tools and Analyses

Achievement Test (AT)

In order to determine and compare students' achievement in the "Sound and its Properties" unit, the researcher developed an achievement test. When preparing the questions, a review of the literature was conducted, and previous studies related to the topic of sound were examined. When creating the question pool, a table of specifications was prepared, and questions were selected to correspond to each learning outcome. The suitability of the questions was checked by an expert and a science teacher. A pilot study was conducted to remove questions with low reliability and discriminative power. There are a total of 25 questions in the achievement test. One point is awarded for each correct answer, and zero points are given for incorrect or blank answers. The maximum score that can be obtained from the scale is 25. The SPSS software package was used to conduct reliability analysis for the development of the achievement scale. The Cronbach's alpha value of the test was found to be 0.90. Additionally, the Kuder-Richardson 20 value, another measure of internal consistency suitable for the structure of the test, was found to be 0.92.

The Scientific Process Skills Test (SPST)

The scale, which is considered to be suitable for assessing students' scientific process skills development, was initially developed by Kenneth G. Tobin and William Capie in 1981.The test, which was adapted into Turkish, has been used by many researchers (Başdaş, 2007 and Türker, 2011). The scale consists of 46 questions with 4 options each. Another adaptation of the scale for middle school 6th-grade level was developed by Türker (2011). As a result of Türker's modifications, the scale was reduced to 25 items, and item analysis and reliability analysis were conducted for the scale. The KR-20 coefficient for the scale was found to be 0.71. In the evaluation of the scale used in the research, one point was given for each correct answer, and incorrect and empty answers were not taken into consideration. The highest score that can be obtained from the scale is 25. The Cronbach Alpha reliability coefficient for the scale was found to be 0.78.

The Motivation Scale for Science Lessons (MSSL)

To examine the changes in students' motivation towards science lessons, the "Motivation Scale for Science Lessons," developed by Dede and Yaman (2008), was used. The scale consists of 23 items. Multiple applications were conducted in the preparation of the scale, and the final application was carried out with 421 middle school students. In order to ensure the validity and reliability of the scale, literature reviews were conducted, expert opinions were sought, and factor analysis as well as Cronbach's alpha coefficient calculations were performed. The scale consists of 23 questions and is based on a Likert-type scale. The scale is rated from 1 to 5, ranging from negative judgments to positive judgments. The maximum score that can be obtained from the scale is 115. The Cronbach's alpha coefficient of the scale was found to be 0.80.

The Implementation Process

The study was completed within five weeks during which the "Sound and its Properties" unit was taught. In the experimental group 1, the Argumentation Supported Model-Based Inquiry (MBI) method was used, while in the experimental group 2, lessons were conducted using the MBI method. The researcher created teacher guide plans and worksheets which cover the objectives of the 6th-grade sound unit. In the experimental group 1, the Argumentation Supported Model-Based Inquiry (MBI) method was implemented. In this method, students first create their mental models and then conduct thought experiments related to them. Students continue their inquiries using the written argumentation method after conducting experiments. As a result of their inquiries, they make adjustments to their mental models. Then, they present their final models to their classmates and provide evaluations. The cycle diagram of the Argumentation-Supported MBI method is shown in Figure 1.

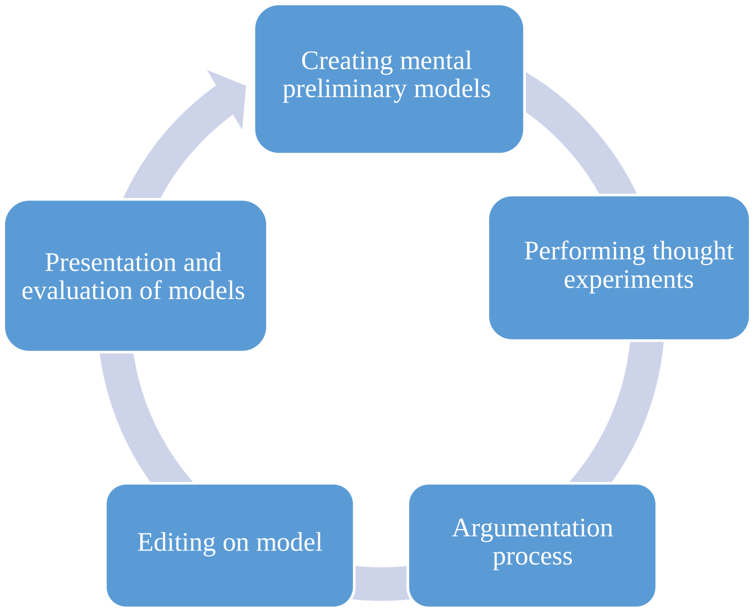

Figure 1. Argumentation-Supported Model-Based Inquiry Method

In the experimental group 2, taught by using the MBI method, students first create their mental models, then conduct thought experiments related to them. Following the inquiries conducted in these two stages, they make adjustments to their mental models and then present the model they have created to their classmates. Finally, they conduct further inquiries to evaluate their mental models. The cycle diagram of the MBI method is shown in Figure 2.

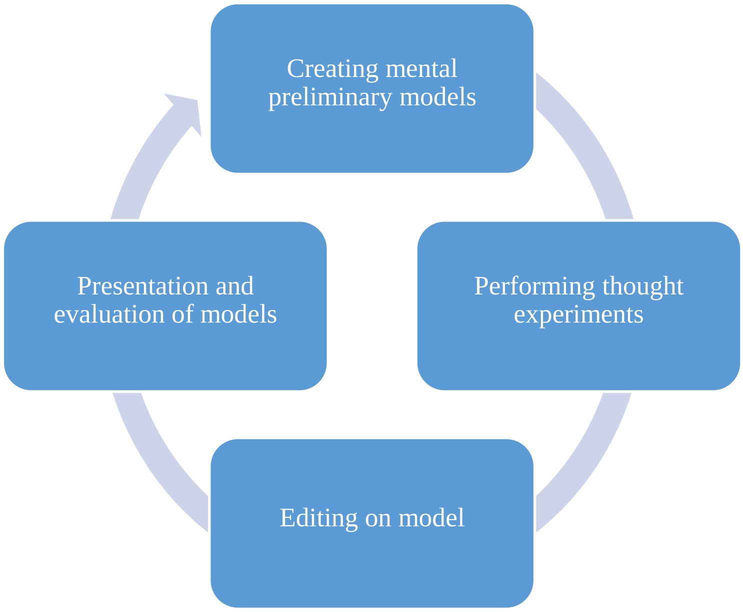

Figure 2. Model-Based Inquiry Method

In the control group of the study, the teacher conducted the lesson according to their own curriculum. In the control group, the unit was covered over a period of 20 lessons, just like in the experimental groups. It was observed that in this group, in which the researcher participated as an observer, science lessons were progressed mostly by following the textbook. It was also observed that in most of the lessons, the teacher lectured only by making a presentation. At the end of the topic, the evaluation questions in the book were solved and student participation was individual and around specific students. The lessons were ended by assigning homework on some pages in the book on the subject.

Results

The results of the data analysis conducted in line with the subproblem of the study are given by classifying them according to the data collection tools.

Findings of the Achievement Test

The means and standard deviations of the pre-test and post-test achievement test scores for the experimental groups and the control group, where "Sound and its Properties" unit was taught using experimental methods and traditional teaching methods, are presented in Table 2.

Table 2. Pre-Post-Test of the Groups for the Achievement Test

Group	N	Pre-test	SD	Post-test	SD
Control	26	9.81	3.06	11.15	4.63
Experimental-1	25	9.88	3.26	15.68	4.94
Experimental-2	26	10.85	3.20	15.58	5.32

According to Table 2, both groups increased their achievement post-test scores. This increase was higher in the experimental groups. A one-way analysis of covariance (ANCOVA) was conducted to determine whether there was a significant difference in the post-test scores of the achievement test among the groups. In the analysis, it was determined that the pre-test scores of the achievement test were covariates for the groups, and accordingly, the post-test scores were adjusted.

Table 3. Mean and Adjusted Mean Scores for the Achievement Test

Group	N	Mean	Adjusted Mean
Control	26	11.15	11.39
Experimental-1	25	15.68	15.87
Experimental-2	26	15.58	15.16

When examining Table 3, it can be seen that the adjusted mean scores for the achievement test's post-test results are 15.87 for Experimental Group 1, 15.16 for Experimental Group 2, and 11.39 for the Control Group. Similar to the mean scores, in the adjusted post-test scores, the experimental groups have higher mean achievement post-test scores compared to the control group. An ANCOVA test was conducted to determine whether this difference was significant, and the findings are presented in Table 4.

Table 4. ANCOVA Results of Achievement Test

Source of Variance	Sum of Squares	sd	Mean Square	F	p
Pre-test	297.46	1	297.46	14.18	0.00
Group	297.51	2	148.76	7.09	0.02
Error	1531.70	73	20.98		
Total	17519. 00	77			

According to Table 4, there is a significant difference in the mean scores of the adjusted post-test scores between the experimental and control groups compared to their pre-test scores. ($F(2,73)= 7,09$; $p < 0,05$). According to the Bonferroni test results, there is a significant difference between the post-test mean scores of the experimental groups and the post-test mean scores of the control group (see Table 5).

Table 5. Comparison of Achievement Test

Related Groups		Difference between Means	p
Control	Experimental-1	-4.48	0.00
	Experimental-2	-3.77	0.01

Related Groups		Difference between Means	p
Experimental-1	Control	4.48	0.00
	Experimental-2	0.71	1.00
Experimental-2	Control	3.77	0.01
	Experimental-1	-0.71	1.00

Findings Regarding the Scientific Process Skills Test

Table 6 describes the means and standard deviations of pre-test and post-test scores on the scientific process skills test for the experimental groups and the control group, where the "Sound and its Proper-ties" unit was taught using traditional teaching methods. According to Table 6, both groups increased their scientific process skills post-test scores. This increase is higher in Experimental Group 1. A one-way covariance analysis (ANCOVA) was conducted to determine whether there was a significant difference in the post-test results of the scientific process skills test among the groups. In the analysis, it was determined that the pre-test scores of the scientific process skills test were covariates for the groups, and accordingly, the post-test scores were adjusted.

Table 6. Pre-Post-Test of the Groups for the Scientific Process Skills Test

Group	N	Pre-test	SD	Post-test	SD
Control	26	9.31	3.32	9.81	4.14
Experimental-1	25	10.36	4.05	14.68	4.20
Experimental-2	26	11.27	4.01	12.46	3.96

In Table 7, the post-test scores of the scientific process skill test were adjusted as 14.68 for experimental group-1, 12.36 for experimental group-2 and 9.91 for the control group. In the adjusted post-test scores, the scientific process skill post-test mean score of experimental group-1 is higher than the other groups. ANCOVA test was performed to determine whether this difference was significant and the findings are shown in Table 8.

Table 7. Mean and Adjusted Mean Scores for the Scientific Process Skills Test

Group	N	Mean	Adjusted Mean
Control	26	9.81	9.91
Experimental-1	25	14.68	14.68
Experimental-2	26	12.46	12.36

Table 8. ANCOVA Results of Scientific Process Skills Test

Source of Variance	Sum of Squares	sd	Mean Square	F	p
Pre-test	11.55	1	11.55	0.68	0.41
Group	285.39	2	142.70	8.45	0.00
Error	1232.39	73	16.88		
Total	8740.00	77			

According to Table 8, it is seen that there is a significant difference between the scientific process skill pre-test scores and corrected post-test mean scores of the experimental and control groups. ($F(2,73)= 8,45$; $p < 0,05$). According to the Bonferroni test results, there is a significant difference in favor of the experimental group-1 post-test mean score (14.68) (see Table 9).

Table 9. Comparison of Scientific Process Skills Test

Related Groups		Difference between Means	p
Control	Experimental-1	-4.76	0.00
	Experimental-2	-2.45	0.12
Experimental-1	Control	4.76	0.00
	Experimental-2	2.31	0.15
Experimental-2	Control	2.45	0.12
	Experimental-1	-2.31	0.15

Findings of the Motivation Scale

Table 10 describes the means and standard deviations of pre-test and post-test scores on the motivation scale for the experimental groups and the control group, where the "Sound and its Properties" unit was taught using traditional teaching methods.

Table 10. Pre-Post-Test of the Groups for the Motivation Scale

Group	N	Pre-test	SD	Post-test	SD
Control	26	89.85	8.80	92.12	9.54
Experimental-1	25	88.96	8.77	98.64	6.93
Experimental-2	26	89.92	12.36	98.38	10.48

According to Table 10, both groups increased their post-test scores on the motivation scale. This increase was higher in the experimental groups. A one-way covariance analysis (ANCOVA) was conducted to determine whether there was a significant difference in the post-test results of the motivation scale among the groups. In the analysis, it was determined that the pre-test scores of the motivation scale were covariates for the groups, and accordingly, the post-test scores were adjusted.

Table 11. Mean and Adjusted Mean Scores for the Motivation Scale

Group	N	Mean	Adjusted Mean
Control	26	92.12	92.16
Experimental-1	25	98.64	98.54
Experimental-2	26	98.38	98.44

In Table 11, the post-test mean scores for the motivation scale were adjusted as 98.54 for Experimental Group 1, 98.44 for Experimental Group 2, and 92.16 for the Control Group. Similar to the mean scores, in the adjusted post-test scores, the experimental groups have higher motivation scale scores compared to the control group. An ANCOVA test was conducted to determine whether this difference is statistically significant, and the findings are displayed in Table 12.

Table 12. ANCOVA Results of Scientific Motivation Scale

Source of Variance	Sum of Squares	sd	Mean Square	F	p
Pre-test	192.06	1	192.06	2.34	0.13
Group	690.17	2	345.08	4.21	0.01
Error	5984.50	73	81.98		
Total	721707.00	77			

According to Table 12, there is a significant difference between the motivation scale pre-test scores and adjusted post-test score means of the experimental groups and the control group ($F(2,73)= 4,21$; $p < 0,05$). According to the Bonferroni test results, the post-test scores of the experimental groups have a significant difference compared to the control group (see Table 13).

Table 13. Comparison of Scientific Motivation Scale

Related Groups		Difference between Means	p
Control	Experimental-1	-6.38	0.04
	Experimental-2	-6.28	0.04
Experimental-1	Control	6.38	0.04
	Experimental-2	0.10	1.00
Experimental-2	Control	6.28	0.04
	Experimental-1	0.10	1.00

Discussion and Conclusion

In this research, lessons were taught using the Model-Based Inquiry (MBI) method and the Argumentation-Supported MBI method with the purpose of improving students' achievements, scientific process skills, and motivation towards the course. By constructing their own models, students can learn abstract information that helps them understand scientific concepts more deeply (Gilbert & Ireton, 2003). Teachers can use models to explain abstract and complex scientific concepts and enable students to develop scientifically accepted mental models of these concepts (Gobert & Buckley, 2000).

According to the results of the study, it has been revealed that the MBI and Argumentation-Supported MBI methods have significantly increased student achievements compared to the traditional method. There are many studies in the literature that suggest that model-based teaching methods are effective in improving student achievement and concept learning (Arslan Buyruk, 2022; Aktaş, 2017; Arslan, 2013; Dauer et al., 2013; Duncan, Freinderich, Chinn & Baushel, 2012; Maia & Justi, 2009; Meng-Fei & Jang-Long, 2015; Trundle, Atwood & Christopher, 2007, Ünal, 2005). According to Hernandez et al. (2015), students' learning can be enhanced through

MBI approaches. The model-based inquiry approach is an important instructional method as it contributes to students' development of their mental models by having them uncover their prior knowledge, engage in inquiry tasks, and then discuss and compare their findings with a scientific perspective.

The difference between the first experimental group, where the Model-Based Inquiry (MBI) method enriched with argumentation was applied, and the second experimental group, where only the MBI method was applied, lies in the fact that in the first experimental group, after students created their models, they engaged in a written argumentation process and then shared it with the class after evaluating their models. The aim was to provide students with the opportunity to enhance their scientific thinking through scientific writing. It is understood that facilitating more in-depth thinking in this manner is effective in improving students' success. There are many studies in the literature which sug-gest that argumentation enhances achievement (Driver, Newton & Osborne, 2000; Akkuş et al., 2007; Aktaş & Doğan, 2018; Çetin et al., 2013; Gençtürk & Türkmen, 2007; Kara, 2019; Günel, Kıngır & Geban, 2012; Aktaş, 2017; Öğreten & Uluçınar Sağır, 2014; Deveci, 2009; Yeşiloğlu, 2007; Büber, 2015; Chen, 2013; Hand et al., 2004). Osborne, Erduran & Simon (2004) are of the opinion that it would be beneficial to use the argumentation method in education. Even discussing very easy topics is important in that it allows students to get involved in the processes that scientists go through. In addition, it is thought that students' discussions with each other, thinking for discussion and creating ideas have an effect on their mental development.

The research has found that the Argumentation-Supported MBI method significantly increased students' scores on scientific process skills compared to the methods used in Experimental Group 2 and the control group. By its nature, the MBI (Model-Based Inquiry) method utilizes the steps of the scientific process. A learning environment that involves the use of scientific process skills requires active student participation. During the instruction process, students construct their mental models by experimenting with their own thoughts and reaching conclusions (Clement, 2000). Even though there are numerous studies on scientific process skills, there is a limited number of research studies that examine the impact of lessons conducted using the model-based inquiry method on students' scientific process skills (Çoban, 2009; Demirçalı, 2022; Loo, 2017). In his study, Arslan (2013) conducted lessons using research-inquiry and model-based research-inquiry methods. As a result, there was no difference in scientific process skills between the two groups. The researcher, who also used qualitative data collection tools in the study, concluded that teacher candidates improved their scientific process skills based on the results obtained from reports and audio recordings. In another study, it was found that modeling positively improved students' scientific process skills, including sub-dimensions such as classification, data interpretation, inference, and model creation (Türker, 2011). While lessons taught using the MBI method improved students' scientific process skills, it has been revealed that the version enriched with argumentation is more effective in enhancing students' scientific process skills. Writing activities help create environments in which students can express themselves more effectively (Akçay et al., 2014). While verbal explanations can sometimes be disjointed, it is known that written explanations tend to be more relevant to the subject matter (Kara, 2019). There are many studies in the literature that suggest that teaching lessons using the argumentation method improves students' scientific process skills (Demirel, 2014; Ceylan, 2010; Şekerci, 2013; Aslan, 2010; Cin, 2013 and Gültepe, 2011).

Another result of the research is that students in the classes where lessons were taught using the MBI methods had significantly higher motivation scale scores compared to the control group's student motivation scores. It is believed that motivation for science classes and the effectiveness of the applied method mutually influence each other and contribute to increasing students' achievement (Alkan & Bayri, 2017). It is believed that the implementation of student-centered methods is one of the important factors that increases students' motivation for science classes. In this study, it can be concluded that the method applied is effective as the students in experimental groups have higher motivation and more successful than the ones in control group. It can be said that students' use of models simplifies complex information and makes the students more active. It can be said that the Argumentation-Supported Model-Based Inquiry method is effective in enhancing students' achievement, scientific process skills, and motivation for science classes, not only because of the advantages brought by modeling but also due to students conducting more detailed inquiries.

Recommendations

This study was set out with the idea that the model-based inquiry method would be more productive for students by enriching it with argumentation activities. The results of this research may be strengthened with similar studies. The methods applied were carried out with students in the 6th grade of secondary school. Future research can be applied to different grade levels and subjects. Besides these, very few studies have been found examining the effect of the model-based inquiry method on students' affective development. This deficiency in the literature can be eliminated by conducting studies examining its effect on students' motivation and attitude towards the course. And since these methods will take a little more time than traditional methods, proper planning should be made and pilot applications should be made before implementation.

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Author Information

Tuğba Geçgil
https://orcid.org/0009-0008-4966-6053
Ph.D. Student
Yıldız Technical University
Institute of Natural Sciences
Turkiye
Contact e-mail: *tugba_gndgd@hotmail.com*

Hakan Akçay
https://orcid.org/0000-0003-0307-661X
Boğaziçi University
Faculty of Education
Turkiye