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Effect of technology-supported argumentation-based instruction in science education on seventh-grade students' motivation toward science course

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ABSTRACT

This investigation was targeted to determine the influence of technology-supported argumentation-based instruction (TSABI) on motivation for the science course (MSC). The investigation group was comprised of seventh-grade pupils in a public middle educational institution in Turkey. The experimental procedure was planned using a pretest-posttest control group quasi-experimental design and implemented for 10 weeks in 2024. Data were collected using the Motivation Scale for Science Course, which was also utilized as a pre-, post-, and follow-up assessment tool. Students selected using the convenience sampling method were assigned to three groups as control, experimental-1, and experimental-2, and were administered student-centered teaching, argumentation-based teaching (ABT), and TSABI, respectively. The pretest points of the study groups were similar at the beginning of the experimentation process; however, the posttest and follow-up test points of the pupils in the experimental-2 class were meaningfully higher than those of the pupils in the control and experimental-1 groups. While the MSC levels of the control and experimental-1 classes did not change over the investigation process, those in the experimental-2 group meaningfully developed and remained unchanged after three months. In addition, the effect size values (η 2) of these analyses are in the high-level range. These results indicated that TSABI is highly effective in the development and permanence of MSC. Based on these results, ABT may be supported with technological applications to motivate students in the ABT process.

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Introduction

Learning experiences should expose learners to questions and, similarly, they should bring scientists into contact with methods used in investigating and answering these questions. For this aim, students should be given the opportunity to conduct scientific research. In addition, learning environments dominated by a scientific approach should be created to conduct discovery, questioning, and analysis. Thus, argumentation should also be included in learning environments (Demir, Enderle & Gül, 2017).

Argumentation is a scholarly debate and social interplay procedure in which scholarly assertions are backed and assessed using experimentation or theoretic proof (Jiménez-Aleixandre & Erduran, 2008). Pupils are expected to construct arguments on scientific topics, question arguments and justifications, and evaluate arguments constructed based on different perspectives to reach scientific explanations in the argumentation procedure (Driver, Newton & Osborne, 2000). Argumentation is also a process of meaningfully connecting the claim, data, rationale, and supporting evidence that make up the fundamental building blocks of an argument (Simon, Erduran & Osborne, 2006).

The argumentation process operates when explaining and questioning how and to what extent the available evidence supports the claim in structuring scientific knowledge and evaluating the scientific nature of a piece of information (Duschl, Schweingruber & Shouse, 2007). Argumentation is a scientific application in that pupils play an active role. In other words, students also participate in the epistemic implementation of science, make scientific claims, justify their claims, create counter-arguments, make evidence-based inferences, and evaluate their claims from a critical perspective during the argumentation process (Özdem-Yılmaz, 2017). The current investigation is also based on the argumentation model that Toulmin developed in 2003. According to this model, datum, assertion, and justification are the basic components of an argument that should proceed from concrete data to the claim, by which the claim should be justified. More complex arguments must include supporting, qualifying, and refuting elements (Toulmin, 2003; Zohar & Nemet, 2002). In short, argumentation is a social procedure of discussion and compromise in which assertions about knowledge are backed and refuted by proof-based data (Demirbağ, 2019).

The argumentation process operates when explaining and questioning how and to what extent the available evidence supports the claim in structuring scientific knowledge and evaluating the scientific nature of a piece of information (Duschl et al., 2007). Argumentation is a scientific application in that pupils play an active role. Argumentation is an imperative element that influences an individual's learning experience. It is a useful tool for conceptual changes to occur. It is a practice of logical thinking or a way of expressing one's thoughts in front of others (Demir et al., 2017). Argumentation assists in the improvement of pupils' verbal and written communication abilities (Sampson, Enderle, Grooms & Witte, 2013). Moreover, it allows personal and social interaction through group discussions and interaction throughout the class (Erduran, Simon & Osborne, 2004). Previous investigations have demonstrated that the application of argumentation in science aids pupils gain scholarly literacy skills (Arduç & Kahraman, 2024; Arslan, 2014, Norris & Phillips, 2003; Tonus, 2012), learn scientific topic (Bell & Linn 2000; Güler, 2023), improve reasoning-critical thinking-decision-making (Arslan & Tüysüz, 2023; Bilasa & Taşpınar, 2018; Karcılı & Sevim, 2024; Lawson, 2003; Yetkil, 2021; Zhou, 2010), understand knowledge (Dawson & Venville, 2010; Jiménez-Aleixandre & Erduran, 2008), increase argument quality (Kara, Yılmaz & Kıngır, 2020), and develop social skills (Kuhn & Udell, 2003).

The linguistic, rational, and social processes in argumentation have led it to be utilized as an essential instructional approach in science instruction (Demirbağ, 2019). Argumentation also has a vital function in the instruction of science (Erduran et al., 2004, Kuhn, 2010; Scott, Asoko & Leach, 2007). Using the argumentation skill, pupils learn to consider different explications in an inquisitive manner, which is a habit of mind of scientists, and critically evaluate the claims, justifications, and arguments put forward in discussions. Therefore, teaching supported with argumentation not only aids pupils to learn scientific topics but also instills in them the routine of considering similarly to scientists. While it influences their interest in and attitude toward science positively, it allows them to gain scientific literacy (Demirdöğen, Yeşiloğlu & Köseoğlu, 2017). The argumentation environment contributes to students' ability to make correct and quick decisions when they face problems or difficult situations in science classes (Tezel, 2018).

Considering the rationale mentioned above, this study addressed argumentation-based teaching (ABT) in science education as the research topic. ABT in science education, in other words, Argumentation-Based Science Learning (ABSL), is a strategy that is centered on research and inquiry and includes linguistic practices such as reading, speaking, writing, and listening (Keys, Hand, Prain & Collins, 1999). ABSL is a practice that allows arguments to be structured in writing (Günel, Kabataş & Büyükkasap, 2010; Kıngır, Geban & Günel, 2013). In ABSL, students ask scientific questions, research these questions, formulate claims based on the data they obtain, and discuss them within a social peer group. Then, they defend their assertions centered on the datum and findings, back up their assertions via proof, evaluate the validity of the evidence based on criteria, evaluate the claims from a critical perspective, report the entire process, and structure knowledge in a research inquiry-based learning environment (Demirbağ, 2019, Günel, Kıngır & Geban, 2012; Jiménez-Aleixandre, 2008; Şahin, 2014). Jiménez-Aleixandre (2008) states that all of these tasks expected from students in the argumentation process are interrelated. This method boosts student attendance in the learning-teaching procedure and provides a greater influential teaching training atmosphere (Günel et al., 2012). During ABSL, individuals go through an argumentation process within a scientific research and inquiry context and discover the path to doing science instead of learning learn the structure of argumentation directly (Cavagnetto, 2010). Compared with activities including inquiry, learning gains are achieved at a high level due to the argumentation process carried out before moving on to the writing stage in ABSL (Akkuş, Günel & Hand, 2007).

A literature review revealed that ABT improved students' argumentation skills (Arslan & Tüysüz, 2023; Atabey & Topçu, 2017; Öğreten & Uluçınar, 2014), thinking skills (Arslan & Tüysüz, 2023; Yıldırır & Nakibioğlu, 2014), achievement (Akkuş & Cevger, 2023; Er & Kırındı, 2020; Öğreten & Uluçınar, 2014), comprehension of concepts (Acar, Tola, Karaçam & Bilgin 2016; Şenel-Çoruhlu & Akyüz, 2021; Tezel &

Yılmaz, 2017), scientific process skills (Er & Kırındı, 2020; Hiğde & Aktamış, 2023), and strategies of cognitive (Aydın & Kaptan, 2014; Ulu, 2019; Ulu & Bayram, 2014). In summary, the application of argumentation in fundamental science lesson teaching contributes to students' critical thinking, problem-solving, communication, scientific reasoning-literacy, logical thinking abilities, encouragement of speaking and writing in science language, cognition and metacognition skills, establishing science culture, and developing epistemological criteria in the evaluation of claims (Jiménez-Aleixandre & Erduran, 2008).

There are quite a few studies discussing the influence of ABT on motivation in the educational literature. Studies reported that argumentation-based flipped learning (Polat, 2025), argumentation-based mathematics education (Türkmenoğlu, 2022), ABSL (Aydın Yalçın, 2019; Bahar, 2023), argumentation-supported peer teaching (Şeker Küçükoğlu, 2023), and ABT (Aydoğdu, 2017) did not make a significant contribution to motivation toward the course. ABSL applied for five weeks (Kara, 2024) and, similarly, a five-week argumentation-supported educational comic books program (Çiçek Şentürk, 2020) had a positive contribution to motivation. Bakdemir (2024) found that approximately six weeks of argumentation-based learning positively contributed to writing motivation. Considering that affective characteristics such as motivation may change in time, it is noteworthy that motivation developed in a relatively short period of 5–6 weeks in the abovementioned studies. In addition, it was seen that the Toulmin model of argumentation, not ABT, was applied as a teaching approach in the study of Çiçek Şentürk (2020). According to most studies in the literature, argumentation does not contribute to motivation, and those suggesting the contribution of argumentation to motivation report that the period of time available is insufficient for motivation to develop and that the stages of ABT are not fully reflected. This requires that ABT be structured to motivate students toward the course and, accordingly, conducting studies discussing the effect of ABT on motivation and the sustainability of motivation. The present is important because it addresses this need in the educational literature.

Investigations in the literature indicate that motivation regarding a course is among the important variables affecting learning (Lazowski & Hulleman, 2016; Wigfield & Wentzel, 2007; Yıldırım & Karataş, 2018). Motivation contributes significantly to the process of meaningful learning in courses such as science, where students experience cognitive difficulties in understanding (Güvercin, Tekkaya, & Sungur, 2010). Therefore, it can be said that teaching processes ought to be planned and implemented in a manner that motivates pupils and sustains their motivation. Accordingly, the current investigation was conducted to obtain answers to the problem of "How can ABT process be designed to motivate students and ensure that motivation is maintained?" This design aimed to make the ABT process interesting and motivating by supporting it with technology. This approach functions as a model example for both educators and investigators. In this context, addressing TSABI as the subject makes the study significant.

To promote the development of students' motivation for learning science, the Self-Determination Theory was used as the basis for designing student-centered teaching, ABT, and TSABI. This theory, developed by Edward Deci and Richard Ryan, addresses changes in personality development and behavioral motivation (Markland, Ryan, Tobin & Rollnick, 2005). Self-determination theory focuses on "intrinsic motivation" and "extrinsic motivation" in individuals' motivation, concentrating on the distinguishing elements between them. Intrinsic motivation is defined as an individual performing a behavior solely to obtain internal satisfaction (Ryan, 1995). Individuals achieve intrinsic motivation when they act purely for pleasure, enjoyment, and satisfaction, or when the activity itself is entirely pleasurable (Howard, Gagné, Morin & Van Den Broeck, 2016). Individuals acting with intrinsic motivation act voluntarily, completely independent of consequences such as rewards or punishments (Vansteenkiste & Ryan, 2013). Extrinsic motivation is defined as individuals performing a behavior for the sake of obtaining a specific result. An individual exhibits a behavior to achieve the outcome of the behavior, rather than for the pleasure derived from performing it (Deci, Vallerand, Pelletier & Ryan, 1991). For individuals with extrinsic motivation, it is not the behavior itself that matters, but rather the most appealing outcome (Ryan & Deci, 2000). In this study, interactive activities that attract students' interest and contribute to their learning through enjoyment and pleasure were used to stimulate students' intrinsic motivation. The technological applications used in the TSABI process are interesting and enable learning through enjoyment.

Educational fields should be open to technological changes and supported by technology appropriately (Başat, 2015) because technology facilitates learning, frees learning from time and place constraints, and can be used for learning purposes outside the classroom environment (Akgün, Özden, Çinici, Aslan & Berber, 2014). The utilization of technology in instructing allows pupils to learn greater easily, quickly, efficiently, and permanently (Ozan, 2009). Teaching can be made easier, more effective, and more enjoyable by incorporating technology into the teaching process (Crompton, Burke & Gregory, 2017). The utilization of technology in science instruction facilitates improving the qualification of science education, developing reasoning skills in science classes, accessing information, improving problem-solving skills, and experiencing situations that are difficult or dangerous to observe in real life (Karamustafaoğlu, Çakır &

Topuz, 2012). Educational technologies have become indispensable in instruction since they make the learning-teaching procedure quirky and attractive, increase memorability with appealing to the senses, embody abstract topics, and ease instructing in tricky or hazardous conditions (Wojciechowski & Cellary, 2013; Yılmaz & Batdı, 2016). In light of this knowledge, the present investigation purposed to motivate students in class by supporting the ABT process with technology due to the interesting, intriguing, and multi-sensory nature of technological applications. Another goal of the present investigation was to make the argumentation procedure, which included scientific discussion and writing, interesting and enjoyable. Accordingly, it can be argued that the study had an original design.

In this study, technological pedagogical content knowledge (TPACK) was used as a basis for supporting ABT with technology, or in other words, for integrating technology into ABT (in the design of TSABI). TPACK is a theoretical framework that explains how technology can be integrated into the learning and teaching process (Yüksel-Arslan, 2013). TPACK is a type of knowledge that is distinct from and transcends the combination of technology, pedagogy, and subject knowledge. TPACK is defined as the teacher's knowledge of which pedagogical techniques should be employed to teach a subject, how to remove barriers to learning, and how technology can be utilized to build new knowledge upon prior knowledge (Mishra & Koehler, 2006). TPACK is a model that teachers must possess in order to integrate technology into teaching (Abbitt, 2011).

The relevant literature includes very few studies on TSABI. Özdem Köse, Bayram and Benzer (2021) examined the influence of argumentation backed by Web-2.0 on success and technology attitude, İnan (2024) simulation-based ABT on written argumentation and reasoning skills, and Akman (2024) digital game-based argumentation on critical thinking and success. Additionally, Yenigün (2024) investigated the impact of ABT backed by Web-2 applications in secondary school science lesson education on creativity, argumentation skills, and success; Torun (2024) TSABI on success, understanding, democratic attitude, and political literacy; Korkmaz (2020) TSABI on comprehension; and Özdem Köse (2019) TSABI on success, comprehension, and argumentative attitude. Önder (2024) examined students' opinions on the argumentation process using GeoGebra. As seen in the educational literature, no study has examined the influence of TSABI on motivation and the sustainability of motivation. The current investigation helps contribute to the relevant literature by filling this gap. Unlike previous studies in the literature, the permanence of learning outcomes was monitored using a follow-up test, the experimental process was fulfilled in 10 weeks, which allowed for changes in affective characteristics, and the entire ABT process was transferred to a digital environment. Moreover, engaging and motivating technological applications were incorporated throughout the ABT process; the TSABI was implemented using tablets and smart boards, and the use of tablets for TSABI enabled pupils to learn at their own pace. Also, the students completed AAFs on tablets. Based on the explanations above, the current investigation was carried out to inquire about the effectiveness of TSABI on motivation regarding science courses (MSC) and the continuance of MSC.

Method

Design of the investigation

This was a quasi-experimental investigation with a pre-posttest control class that investigated the effect of TSABI on MSC. In the study, experimental procedures were utilized for the control-experimental classes. The participating pupils were selected from the seventh-grade branches of the school where the investigation was carried out, and the TSABI was utilized as a pre-, post-, and follow-up test (Büyüköztürk, 2024).

Characteristics of the investigation groups

The pupils were placed into three groups: control, experimental-1, and experimental-2. There were 31 (female=16, male=15) in the control, 30 (female=16, male=14) in the experimental-1, and 30 students (female=male=15) in the experimental-2. All of the pupils lived in the same neighborhood and were between the ages of 13–14. Based on this information, it was concluded that the pupils in the study classes were alike with respect to sex and socioeconomic status.

Sampling method

The researcher chose the branches of the school where he/she worked as the study group so that he/she would not encounter any difficulties in implementing the experimental procedure. Thus, an appropriate sampling technique was employed in the investigation (Büyüköztürk, Kılıç-Çakmak, Akgün, Karadeniz & Demirel, 2024). The researcher works as a science teacher at a state middle school and teaches science classes every day between 9:00 a.m. and 4:00 p.m. This situation prevents the researcher from conducting fieldwork at another school. For this reason, the researcher used the students at his own school as a sample.

The limitations of the appropriate sampling method are the inability to collect sufficiently rich information to see the logical connections between events, and the researcher's biased behavior (Büyüköztürk et al. 2024, Kılıç, 2013; Yıldız, 2017). The researcher is both the teacher and the implementer of the control, experimental-1, and experimental-2 groups. This situation may lead to the researcher's biased behavior. To prevent the researcher from acting biasedly, a second science educator participated as an observer in some lessons alongside the researcher. The second science educator examined whether the researcher acted biasedly during the teaching process in the control, experimental-1, and experimental-2 groups. Thus, the researcher factor, which threatened internal validity, was prevented.

Data collection tools

Motivation Scale for Science Course (MSSC)

The MSSC, designed by Dede and Yaman in 2008, was used to assess the participating students' MSC levels. The MSSC is a five-point likert scale with 23 items, including 20 positive and 3 negative expressions. The positive items are scored as "StronglyAgree:5, Agree:4, Somewhat Agree:3, Disagree:2, StronglyDisagree:1" and negative questions are reverse graded. The structure validity of the MSSC was determined utilizing exploratory factor analysis, which revealed that the scale had five factors and explained 47% of the total variance. Cronbach's alpha was used in the reliability analysis of the MSSC, and it was 0.85 for the data obtained from 352 students. The reliability analysis of the MSSC was repeated with 319 students after three weeks, and it was found to be 0.82 (Dede & Yaman, 2008).

The MSSC was administered to 413 seventh-grade students before the present study was conducted, and its reliability was 0.87. A coefficient higher than 0.70 indicates the reliability of the MSSC. The suitability of the items in the MSSC to measure the MSC was examined using an expert evaluation form. Accordingly, the opinions of two science educators were sought, and it was concluded that the items were suitable for measuring the MSC.

Data analysis

The distribution structure of MSSC data was examined, and the results are shown in Table 1.

Table 1. Analysis of the MSSC data's normality

Group	Test	Skewness	Kurtosis	Shapiro W.
Control	MSSC Pre	0.21	-0.88	0.36
	MSSC Post	0.26	-0.66	0.77
	MSSC Follow-up	0.33	-0.59	0.52
Experimental-1	MSSC Pre	-0.24	-0.54	0.82
	MSSC Post	-0.17	-0.32	0.34
	MSSC Follow-up	-0.20	-0.19	0.80
Experimental-2	MSSC Pre	-0.29	-0.83	0.48
	MSSC Post	-0.31	-0.91	0.36
	MSSC Follow-up	-0.41	-084	0.12

Table 1 indicates that the skewness-kurtosis of the MSSC data were in the interval of -1.5 to +1.5 and that the meaningful result of the Shapiro-Wilk test was bigger than 0.05. This can be interpreted as the fact that the MSSC data had a normally distributed structure (Büyüköztürk, 2024). Therefore, the MSSC data of the investigation groups were investigated using the independent groups t-test, and the change in the MSSC pre-, post-, and follow-up test points was examined utilizing the ANOVA for repeated measures. The eta squared (η 2) impact size was computed in the analyses where significant differences were found. The η 2 effect size was commented as follows:0.01< η 2<0.06 indicated a low impact, 0.06≤ η 2<0.14 a moderate impact, and 0.14≤ η 2 a high impact.

The homogeneity of variances in t-test analyses for independent groups was examined using the Levene Test. Since the significance values of the Levene test were higher than 0.05 in all analyses, the variances of the groups were considered homogeneous. In addition, the assumptions for "One-Way ANOVA for Repeated Measures" were examined. First, the distribution of the research data was examined using skewness and kurtosis coefficients, as well as the Shapiro-Wilk analysis. The results of these analyses showed that the research data were normally distributed. Mauchly's Test of Sphericity was used to examine whether the covariance structures between measurements were homogeneous. In the repeated measures ANOVA analyses, the sphericity significance values were greater than 0.05. Therefore, it was assumed that the covariances between measurements were homogeneous. Based on these results, the assumptions for the one-way ANOVA for repeated measures were met.

Implementation of the study

Prior to the implementation phase of the study, both ethical committee approval and Ministry of National Education implementation approval were obtained. Before the study, student parents and students were informed about the research and data collection process. A Parental Consent Form was obtained from parents who wished to voluntarily participate in the study.

Pupils in the class under control received student-centered instruction, those in the experimental-1 class ABT, and those in the experimental-2 class TSABI. The duration of the investigation was 10 weeks and 40 lessons, excluding the time for application of the measurement tools. MSSC was applied as a pretest at the initial stage of the experimentation procedure, a posttest at the completion of the experimental process, and a follow-up test 90 days following the completion of the experimental process.

Implementation in the control class

The unit "Light" was instructed in the control group utilizing student-centered teaching methods. Textbooks and supplementary books were used to provide learning targets of the 2018 7th-grade science course program, and the unit was taught along with student-centered lessons grounded in learning-teaching by doing and experiencing.

Implementation in the Experimental-1 and Experimental-2 classes

The same unit "Light" was taught applying ABT in the experimental-1 and TSABI in experimental-2 classes. The first and second weeks were planned for argumentation for both groups, and argumentation and the topics of the unit "Light" were taught. Argumentation training was given for students to understand argumentation, apply the argumentation process, and conduct research in line with the goals of the investigation. In the 8 weeks between weeks 3 and 10, the unit was taught using ABT in experimental-1 and TSABI in experimental-2 classes.

The first week was planned for preparation, and the elements of argumentation, which were argument, counterargument, refutation, and how the argumentation process occurred, were explained with examples to the experimental groups. In addition, characteristics that a qualified argument should have were emphasized. It was noted that to achieve high-quality argumentation, students could present a counterargument to arguments, that discussion played an essential function in convincing pupils of the counterargument, and that it was important to present evidence during the discussion process to prove that a student's argument was correct and to refute the counterargument. It was also emphasized that during the discussion process, it is important to present evidence to prove the validity of one's argument and to refute the counterargument. Then, the pupils in the experimentation groups were requested to present their arguments, counterarguments, and refutations on a sociological topic. The pupils in the experimental groups were split into groups of 4-5 pupils, and each student in the groups was given an AAF on the topic of "Laboratory Animals." The topic on the AAF was about the question, "Is the utilization of animal experiments in scientific investigation an advantage for humanity, or is it an injustice to the lives of these animals?" The pupils in the classes examined the text on the AAF, explained their opinions within the group, and discussed them. Then, a general discussion was held in the class, and the pupils expressed their views. At the conclusion of the class discussion, each student expressed their written arguments on the AAF. The students were informed that they were allowed to change their opinions at the conclusion of the discussions. Pupils in the class could have different opinions. One of the essential factors in argumentation was that every pupil could defend their opinions and identify the weaknesses of the opposing opinion and neutralize them. Points to be considered in explaining the elements of argument, counterargument, and refutation in a quality argument were also indicated. In the assessment of AAF, the scores that could be obtained depending on the number of reasons and supporting evidence provided, and the minimum requirements for achieving the highest score in each element of argumentation, were also outlined with examples.

In the second week of preparation, the lesson was instructed to the pupils in the experimental-1 class using ABT. For the pupils in the experimental-2 class, argumentation was transferred to a digital platform thanks to technological support and implemented using smart boards and tablets. As of the second week, the ABT process was incorporated into technological applications such as Plotagon, ElevenLabs, and CapCut in the experimental-2.

The "Light" unit was taught to the pupils in the experimental groups with eight argumentation activities in weeks from 3 to 10 (8 weeks). For this purpose, AAF was used in both groups. It was ensured that the technological assistance supplied in the experimental-2 class was compatible with both the outcomes of the Light unit and the features of argumentation.

In the experimental-2 class, brainstorming activities were performed using the WordArt program from weeks 3 to 10, and tests were administered at the beginning of the lesson using the Plickers application to see the students' ideas and previous knowledge about the subject. Animation was also utilized to inspire pupils' attention in the topics and motivate them. The argumentation technique, which allowed the development of gains, was transferred to the digital environment in a way that includes interesting and motivating multimedia elements, thanks to technological applications. The CapCut program was used to transfer competing theories to a digital platform, a method used to initiate the argumentation process. Subsequently, the entire argumentation process was transferred to a technological application.

Students were asked questions about the theories that compete with technological applications, and their predictions were taken. Then, the student groups conducted a simulation for the competing theories by manipulating the parameters, and the conclusions were observed. The students examined whether their predictions about the competing theories were confirmed or not based on their observations they made in the simulation, and tried to explain the outcomes within the group. The simulation and argumentation process completed by pupils using tablets provided them with the possibility to learn at pupils' own instruction speed. In addition, transferring the argumentation process to the digital environment and making it available to students through tablets provided the opportunity to perform a study on argument, counterargument, and rebuttal, and to participate in student-interactive practice, application, assessment, and evaluation activities.

Students performed the digital simulation and competing theories activity using tablets. They were asked to choose the theory that could explain the events and questions in the scenario of the competing theories. Then, the students were instructed to discuss the theories they chose within their groups in the digital environment. Subsequently, in the same environment, pupils were requested to create their claims, justifications, and supporters for the argument, justifications and rebuttals to refute the argument of the students with different opinions in the group, or to support their arguments, and supporting and refuting ideas.

Students filled out AAFs while the argumentation process in the digital environment was carried out with the support of technology, including multimedia elements. At the end of the argumentation process, a discussion environment was established in the classroom, aiming to attain answers, conclusions, and generalizations about the events, questions, and theories in the competing theories. Measurements throughout the argumentation process were carried out using technological applications (e.g., Plickers) to determine students' previous knowledge, learning deficiencies, and learning level.

The ABT process applied to the experimental-1 group was planned and implemented similarly to the TSABI process applied to the experimental-2 group, without using technological applications. In addition, the same AAF was used in the argumentation process in both experimental groups.

Findings

Table 2. Examination of MSC pretest points of the control and experimental-1

Group	N	x̄	S	df	t	p
Control	31	79.97	12.54	59	0.15	0.88
Experimental-1	30	79.50	12.46			

Based on the outcomes in Table 2, there was no meaningful differentiation among the MSC pretest points of the control and experimental-1 groups ($t_{(59)}=0.15; p>.05$).

Table 3. Examination of MSC pretest points of the control and experimental-2

Group	N	x̄	S	df	t	p
Control	31	79.97	12.54	59	0.82	0.73
Experimental-2	30	79.23	13.20			

The information in Table 3 revealed no meaningful differentiation in the pretest points of the control and experimental-2 groups ($t_{(59)}=0.82; p>.05$).

Table 4. Examination of MSC pretest points of the experimental-1 and experimental-2

Control	N	x̄	S	df	t	p
Experimental-1	30	79.50	12.46	58	0.08	0.94
Experimental-2	30	79.23	13.20			

As observed in Table 4, the MSC pretest points of the control and experimental-2 groups were alike ($t_{(58)}=0.08; p>.05$).

Table 5. Examination of MSC posttest points of the control and experimental-1

Group	N	x̄	S	df	t	p

Control	31	80.74	14.06	59	0.23	0.83
Experimental-1	30	79.97	13.12			

The conclusions in Table 5 indicated that the differentiation among the MSC posttest points of the control and experimental-1 classes was not meaningful ($t_{(59)}$=0.23; p>.05).

Table 6. Examination of MSC posttest points of the control and experimental-2

Group	N	x̄	S	df	t	p	η2
Control	31	80.74	14.06	59	-2.97	0.004	0.13
Experimental-2	30	91.47	14.11				

It can be argued that the MSC posttest points of the experimental-2 class were meaningfully greater than those of the control class ($t_{(59)}$= -2.97; p<.05). The η2 value in the table indicates that the effect of the experimentation application was moderate (Table 6).

Table 7. Examination of MSC posttest points of the experimental-1 and experimental-2

Group	N	x̄	S	df	t	p	η2
Experimental-1	30	79.97	13.12	58	-3.27	0.002	0.16
Experimental-2	30	91.47	14.11				

Table 7 demonstrates that the MSC posttest points of the experimental-2 class were meaningfully greater than those of the control class ($t_{(58)}$= -3.27; p<.05). Considering the η2 values in the table, the influence size may be interpreted to be big.

Table 8. Examination of MSC follow-up test points of the control and experimental-1

Group	N	x̄	S	df	t	p
Control	31	81.10	13.84	59	0.44	0.66
Experimental-1	30	79.57	13.52			

As Table 8 shows, the MSC follow-up test points of the control and experimental-1 classes were similar ($t_{(59)}$=0.44; p>.05).

Table 9. Examination of MSC follow-up test points of the control and experimental-2

Group	N	x̄	S	df	t	p	η2
Control	31	81.10	13.84	59	-2.84	0.006	0.12
Experimental-2	30	91.30	14.21				

Based on the information in Table 9, the MSC follow-up test points of experimental-2 were meaningfully greater than those of the control class ($t_{(59)}$= -2.84; p<.05). The η2 values in the table demonstrate that the influence size was high.

Table 10. Examination of MSC follow-up test points of the experimental-1 and experimental-2

Group	N	x̄	S	df	t	p	η2
Experimental-1	30	79.57	13.52	58	-3.29	0.002	0.16
Experimental-2	30	91.30	14.21				

As Table 10 shows, there was a meaningful differentiation in the side of the experimental-2 class among the MSC follow-up test points of the experimental-2 and the control classes ($t_{(58)}$= -3.29; p<.05). In addition, the influence size was big.

Table 11. Examination of MSC pre-post-follow-up test points of the control class

Variance's Source	Square's Sum	df	Square's Mean	F	p
BetweenSubjects	15734.946	30	524.498	0.94	0.40
Measurement	20.667	2	10.333		
Error	660.667	60	11.011		
Total	16416.28	92			

The conclusions stated in Table 11 showed that there was no meaningful differentiation among the MSC pre-, post-, and follow-up test points of the pupils in the class under control ($F_{(2-60)}$= 0.94; p>.05).

Table 12. Examination of MSC pre-post-follow-up test points of the experimental-1 class

Variance's Source	Square's Sum	df	Square's Mean	F	p
BetweenSubjects	13976.322	29	481.942	0.14	0.87
Measurement	3.822	2	1.911		
Error	815.511	58	14.061		
Total	14795.655	89			

Considering the significance value in Table 12, there was no meaningful differentiation among the MSC pre-, post-, and follow-up test points of the pupils in the experimental-1 class ($F_{(2-58)}$= 0.14; p>.05).

Table 13. Examination of MSC pre-post-follow-up test points of the experimental-2 class

Variance's Source	Square's Sum	df	Square's Mean	F	p	η2	Difference

BetweenSubjects	15486.000	29	534.000				
Measurement	2952.867	2	1476.433	71.18	0.001	0.71	Post-Pre, Follow up-Pre
Error	1203.133	58	20.744				
Total	19642.000	89					

The results presented in Table 13 showed a meaningful differentiation in support of the posttest points among the MSC pre-posttest points in the experimental-2 class. Similarly, there was a meaningful differentiation in support of the follow-up test among the MSC pretest-follow-up test scores. There was no meaningful differentiation among the MSC posttest-follow up test points ($F_{(2-58)}$= 71.18; p<.05). Based on the η2 value, it can be argued that TSABI had a large influence on the development of MSC.

Discussion

The current investigation examined the effect of TSABI on MSC compared with student-centered instruction and ABT. In the class under control, student-centered teaching was applied instead of teacher-centered teaching, thereby the pupils in the control class were not put at a disadvantageous while teaching the “Light” unit. The study specifically compared the effect of TSABI on MSC compared with that of ABT; the reason for this was to determine whether the improvement in MSC scores of the experimental class to which TSABI was utilized was caused by AB or TSABI.

The MSC scores of all study groups were similar at the beginning of the experimental process. This was an appropriate result in terms of comparing the effect of TSABI implemented to the pupils in the experimental-2 class on MSC with student-centered instruction and ABT. The MSC post-follow-up test points of the pupils in the experimental-2 class were meaningfully bigger than those of the control-experimental-1 classes. In other words, this proved that TSABI was more effective in the development and permanence of MSC compared with student-centered instruction and ABT. This conclusion may be ascribed to the truth that the ABT process was transferred to the digital environment by including interesting and motivating multimedia elements with a technological application; in other words, ABT was supported with technology. Furthermore, the MSC post-follow-up test points of the control-experimental-1 classes were similar, which can be explained by the fact that ABT was also student-centered teaching, and student-centered teaching was implemented in both control and experimental-1 groups.

No meaningful improvement occurred in the MSC scores of the control class, although student-centered teaching was applied. This may be explained by the fact that the researcher taught a science course to the control group students, consisting of seventh-graders, when they were fifth- and sixth-graders, and a student-centered teaching method was employed in the science lesson.

There was no meaningful improvement in the MSC points of the pupils in the experimental-1 class to whom ABT was utilized. The researcher interviewed the pupils in the experimental-1 class at the end of the study to clarify this situation. By the end of the conversations, it was understood that almost all of the pupils found completing AAF in written form and the argumentation process boring. AAF was a form in which the students’ argumentation process was documented while the process was carried out. In this context, the fact that no significant change occurred in the MSC level can be explained by the reluctance to write and feeling bored of the pupils in the experimental-1 class when filling out the AAF. The result that ABT did not bring about a meaningful improvement in MSC scores in the present study is similar to those in the educational literature. For instance, supporting the conclusions of the present investigation, argumentation-based flipped learning (Polat, 2025), argumentation-based mathematics education (Türkmenoğlu, 2022), ABSL (Aydın Yalçın, 2019; Bahar, 2023), argumentation-supported peer teaching (Şeker Küçükoğlu, 2023), and ABT (Aydoğdu, 2017) did not make a significant contribution to motivation toward the course. ABSL applied for five weeks (Kara, 2024) and, similarly, a five-week argumentation-supported educational comic books program (Çiçek Şentürk, 2020) had a positive contribution to motivation. Bakdemir (2024) found that approximately six weeks of argumentation-based learning positively contributed to writing motivation. Considering that affective characteristics such as motivation may change in time, it is noteworthy that motivation developed in a relatively short period of 5–6 weeks in the abovementioned studies. Motivation is an emotional trait that can change in a long time. Accordingly, the 5–6-week implementation period of the studies conducted by Kara (2024), Çiçek Şentürk (2020), and Bakdemir (2024) can be interpreted as too short for the development of these characteristics. In addition, it was seen that the Toulmin model of argumentation, not ABT, was applied as a teaching approach in the study of Çiçek Şentürk (2020). Thus, it can be argued that the studies reporting the contribution of ABT to motivation did not have a sufficient length of time for the development of motivation, and the stages of ABT were not fully reflected. This shows the differences between the present and the abovementioned studies.

There was a meaningful increase in the MSC points of the pupils in the experimental-2 class, and this increase was maintained after three months, showing that TSABI had a significant function in the growth of

MSC and in ensuring its permanence. This result can be attributed to the technological support provided to the ABT process in the implementation of TSABI. In other words, this was achieved by transferring ABT to a digital platform with a structure that included audio-visual-motion elements, that is, multimedia elements, that could attract students' attention and motivate them to learn, thanks to technological applications. The ABT process in TSABI was transferred to a digital environment using the Plotagon, ElevenLabs, and CapCut applications. In addition, simulation tools (e.g., PhET-Colorado, Algodoo) suitable for the gains of the "Light" unit and the nature of argumentation were also used. Additionally, this result can be explained more broadly by the things done in the implementation procedure of the investigation. Students' opinions about the topic were determined using the brainstorming technique in the Wordart application, and their prior knowledge was examined employing tests in the Plickers online tool. Animations were used to attract students' interest and provide motivation.

Both the "t-Test for Independent Groups" and the "One-Way ANOVA for Repeated Measures" analyses yielded effect size values in the high range. This result can be interpreted as indicating that TSABI has a high level of effectiveness in developing and sustaining motivation. Considering this result and the positive impact of motivation on learning outcomes, it can be said that teaching c be supported by technology to motivate students to learn science. Thus, more effective science teaching can be achieved with the support of technology.

The argumentation technique, which can contribute to the development of the gains, was moved to the digital platform to include interesting and motivating multimedia elements. Thanks to the simulation and argumentation process completed by the students using tablets, they were enabled to learn at their own learning pace. In addition, the transfer of the argumentation process to a digital environment and making it available to students through tablets provided the opportunity to conduct a study on arguments, counter-arguments, and rebuttals, and to participate in student-interactive practice, application, measurement, and evaluation activities. Students were allowed to fill out the AAF without getting bored during the argumentation process in the digital environment. Throughout the argumentation process, students' prior knowledge, learning deficiencies, and learning levels were measured using technological applications (e.g., Plickers). These activities carried out in the TSABI contributed to the improvement of MSC.

This conclusion may also be explicated by the knowledge that teaching environments enriched with interactive and multimedia elements, thanks to technology, were created (Mayer, 2009), multiple sensory organs were addressed (Krouska, Troussas & Sgouropoulou, 2020), and content suitable for students' individual speed and needs was developed (Means, Toyama, Murphy, Bakia & Jones, 2009). In addition, the argumentation process was made fun and interesting with interactive applications (Erduran et al., 2004). Thus, pupils' participation in the learning procedure was provided, and their motivation increased (Sevigen, 2022).

Thanks to the rapid development in technology, the tools used in educational activities are increasingly renewed, making the course more interesting, improving pupils' interest in the class, and facilitating their learning (Kıyıcı & Yumuşak, 2005). The utilization of technology in instruction provides individualized learning opportunities by identifying students' strengths and weaknesses (Gökmen et al., 2016). Thanks to technology, students enrich their learning experiences with interactive activities and can proactively take part in the learning procedure. This allows students to proactively take part in the learning procedure rather than passively listening (Ministry of National Education, 2024). Thus, the utilization of technology in instruction supplies the possibility to provide effective education by enriching traditional classroom environments (Aşık et al., 2023). In summary, the utilization of technology in instruction can encourage student interaction and participation, support visual and auditory learning, and increase interest and motivation by making learning more enjoyable (OECD, 2021). With the information provided above, the results of the research can be explained more broadly.

TSABI's contribution to motivation in science classes can also be explained by its provision of intrinsic motivation, which forms the basis of self-determination theory. Individuals have intrinsic motivation when they seek pleasure, enjoyment, and satisfaction, or when the activity itself is pleasurable. The technological applications used in the TSABI process are also interactive, triggering students' intrinsic motivation. In other words, they attract students' interest and contribute to their learning while they have fun and enjoy themselves.

The use of pedagogical techniques in supporting ABT with technology (in the design and implementation of TSABI), in other words, the use of TPACK, may have contributed to maintaining interest in teaching. It can be said that this situation may have had a positive impact on motivation.

Students have not previously received technology-enhanced instruction. In this study, supporting ABT with technological applications that foster intrinsic motivation (through the implementation of TSABI) provided students with an innovative teaching experience. This may have contributed to the development of motivation.

The limitation of this study is the use of an appropriate sampling method. This situation may lead to bias on the part of the researcher and prevent the collection of sufficiently rich information. To eliminate this limitation, it is recommended that studies be conducted using a random sampling method and that quantitative and qualitative data collection tools be combined.

Conclusions and recommendations

The current investigation demonstrated that the utilization of TSABI in science education significantly affected the development and permanence of MSC. This conclusion may be explicated by the truth that ABT was moved to a digital platform where multimedia elements were used, the ABT process included interesting and motivating student-interactive animation, simulation, assessment, evaluation and learning activities, the technological applications used in ABT were also suitable for students with different learning styles, these technological applications could activate more than one of the senses, pupils performed student-interactive teaching activities at their own pace through tablets, and tablets were used in completing AAFs. In short, this result was due to the transformation of ABT into an interesting and motivating process, in other words, TSABI, by supporting it with technological applications.

Based on the positive effect of TSABI on MSC, the argumentation process may be supported by technological applications to attract students' interest, motivate them to learn, and make this process more engaging and enjoyable rather than boring. In other words, it may be suggested that TSABI may also be included in the science teaching process. It may be said that in the design of TSABI, attention can be paid to integrating technological applications with pedagogy and subject knowledge, as in this study.

This study examined the effect of TSABI on motivation toward science courses using quantitative research methods. The effects of TSABI on other variables can be examined in longer-term studies. It is also recommended that studies on TSABI be designed using mixed methods that combine quantitative and qualitative research methods. In this study, the TPACK model was used as the basis for integrating technology into the argumentation process. It is recommended that studies on TSABI be designed using different technology integration models.

Declarations

Ethics statements

The research was conducted according to ethical considerations.

Informed consent

Written consent was obtained from all participants.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Competing interests

No potential conflict of interest was reported by the author(s).

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Authors' contributions

Two authors took equal part in the conduct and reporting of the research.

Artificial Intelligence

Artificial intelligence was not used in the preparation of this article.

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