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An evaluation of academic achievements through the use of argument and concept maps embedded in argumentation based inquiry

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Abstract
This mixed-method study aimed to compare the academic achievements of students to their use of argument maps and concept maps in learning environments designed for argument-based instruction (ABI). The study was conducted during the spring term of the academic year 2018–2019 with the students of three sections of grade six instructed by the same teacher at a secondary school in the province of Kastamonu. Before the study began, one of the participating sections was randomly designated as the control group, while the other two were assigned as the experimental group. The control group students undertook research interrogation-based activities during lessons and individually reported activities appropriate for the ABI student template for each activity. The experimental group students handled ABI applications. In addition, one section of the experimental group prepared concept maps, while the other section made argument maps. The 5-week study was accomplished during the instruction of the "sound and its properties" unit of the curriculum. The data were acquired via a pre- and post-administration of the unit-based success test to measure academic success. Further, semi-structured interviews were conducted to ascertain the opinions of students vis-à-vis the pedagogy. The obtained quantitative data were analyzed using the ANCOVA analysis via the SPSS software. The qualitative data collected through semi-structured interviews were examined by the creation of themes, codes, and frequencies. The experimental group using argument maps or concept maps in addition to ABI applications revealed significant outcomes in terms of academic achievements. Further, students expressed the belief that argument and concept maps helped them learn and remember the topic.

Keywords Argumentation · ABI · Argument map · Concept map

Introduction

In recent years, researchers and teachers have accorded particular importance to the understanding of scientific concepts, which students generally find difficult to apprehend (Yağbasan & Gülçiçek, 2003). It is thus necessary to make students think and to show them varied ways and means of accessing the requisite information rather than to consistently offer them ready knowledge (Ayas, 1995). Additionally, research interrogation environments must be grounded on enabling the active participation of students in the learning process to determine how they can acquire and use scientific knowledge and how they can assure the accuracy of the acquired learning (Özcan, 2016).

Creating learning environments in which students can freely express their opinions encourages learners to express their ideas and to develop their reasoning and communication skills (MEB, 2018). The learning process comprises exploration, interrogation, argumentation, and product design (MEB, 2018). The provision of environments in which students can discuss the associations among scientific phenomenon is necessary for them to be able to express their opinions freely, support their ideas through varied rationales, and develop counter arguments against the contentions of their peers (MEB, 2018). In such environments, students can develop their cognitive skills, think differently, increase their conceptual understanding, and develop their research skills and epistemological understanding (Driver et al., 2000; Yalçın-Çelik, 2010). Also, scientific discussions can

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enable students to reveal their thoughts about the contents of subjects, structure new concepts, and contemplate their own inadequacies (Akpınar & Ergin, 2005).

With regard to the contributions of scientific discussion environments to the educational process, the Argumentation-Based Inquiry (ABI) approach allows for such discussions (Baydas et al., 2018) because it can create a learning environment in which learners can structure their own knowledge through communication and collaboration. Put differently, students can apply active intraclass interactions to processes such as writing, reading, searching, discussing, questioning, trying, and interpreting information (Keys et al., 1999).

The Argumentation-Based Inquiry approach aims to help students posit points of view via scientific questioning (Choi et al., 2010) and bolsters scientific discussions (Hand & Norton-Meier, 2011). The approach includes scientific thinking, writing, and discussion processes. The argumentation at the center of the ABI methodology may be defined as the process of achieving rational decisions to elucidate the contradictions between two opposing situations (Kaya & Kılıç, 2008). Scientific argumentation encompasses the process of establishing both experimental and theoretical connections between hypotheses and data along with appropriate justifications (Erduran & Jimenez-Aleixandre, 2007). Students must use decision-making strategies in scientific thinking and writing activities by asking questions, testing evidence, making parallel claims, and comparing their postulations against existing scientific knowledge (Hand, 2008; Hand et al., 2004; Martin & Hand, 2007). Students participate in discussion activities in both small units (intra-group) and large groups (whole classroom) during and after they experience the argumentation process (Baydas et al., 2018). Students can thus structure knowledge using their inquiry skills throughout the process. During this structuring process, students experience an argument cycle through constant communication with their peers and teachers. The ABI approach accords students with the opportunity to structure nuanced domain-related information (Hasançebi & Günel, 2013) and can thus help students to enhance their conceptual knowledge.

Meaningful learning occurs when a student restructures newly acquired knowledge within an existing conceptual framework and establishes new meanings and relationships (Novak & Canas, 2006). Meaningful learning is defined as a cognitive structure that facilitates the storage and recall of knowledge within a specific order in memory (Gul & Boman, 2006; Novak, 2010). Meaningful learning becomes possible when a student groups and formulates knowledge step by step (Çakıcı et al., 2006) in a manner resembling the construction of an edifice: the stability of a structure is questionable unless its foundation is strong. Hence, the apprehension of domain-related learning cannot transcend rote-knowledge unless the learning is strongly grounded (Sökmen et al., 2000). Meaningful learning depends on the presence of topic-related concepts, principles, or ideas in a student's cognitive structure, the student's willingness to learn and understand, and the student's assignation of importance to the new material to be learned (Ausubel, 1968). No meaningful learning is possible unless these conditions are met (Ausubel, 1968). The prior learning acquired by the student represents the most important factor influencing new learning (Çakıcı et al., 2006). Therefore, previously acquired knowledge must be revealed and prospective instruction should be accordingly planned. The significance of meaningful learning is widely acknowledged; however, studies on methods of imparting meaningful learning continue to be conducted (Ahlberg, 1993; Dikici et al., 2010; Ekmekçioğlu, 2007; Yılmaz & Çolak, 2011) to prove the importance of meaningful learning. Classroom instruction that utilizes mapping methods such as argument maps, concept maps, or mind maps enables students to actively participate in lessons and experience meaningful learning (Davies, 2011). Additionally, the usage of verbal expressions and images in mapping methods contributes to student learning (Twardy, 2004). Davies (2011) separated the objectives of mapping methods into three categories: effectuating meaningful learning through the recall of knowledge, helping to make knowledge more usable by building new materials on the basis of existing knowledge, and enabling students to acquire new and meaningful accumulations of knowledge by encouraging them to actively participate in the lessons. The extant literature indicates the value of the use of mapping tools for the efficacious presentation of the knowledge to be imbibed within appropriately designed learning environments (Cook, 2006; Harrell, 2011). Mapping tools enable people to visually present meaning that has been personally structured for a knowledge domain (Canas et al., 2005). These tools allow learners to develop profound, cognitive, and self-regulated strategies for the learning process and trigger meaningful learning or conceptual inferences (Chin & Brown, 2000). The primary objective of mapping tools is to display similarities; however, they are different in practice (Eppler, 2006).

Concept mapping

Concept maps are visual tools prepared to ensure effective and meaningful learning in congruence with inter-conceptual relationships and resolutions based on such associations (Kaşlı et al., 2001). Concept maps enable students to meaningfully learn course subjects by establishing connections between concepts taught in subject-specific curricula (Barut, 2006). Concept maps aim to determine the framework of relationships between elements rather than to automatically produce associations (Barut, 2006; Kabaca, 2002; McGowen & Tall, 1999; Suen et al., 1997). The generation of concept maps represents a vital strategy for the disclosure of existing theoretical structures in the minds of students (Novak & Gowin, 1984). Therefore, more general and inclusive concepts are placed at the top of a hierarchically arranged concept map, whereas more specific and less inclusive notions are assembled below (Novak & Gowin, 1984). The hierarchical quality of concept maps allows new concepts or concept areas to become more inclusive and comprehensible, thus improving meaningful learning (Novak & Gowin, 1984). In this context, it was hypothesized that concept maps prepared after ABI applications were presented by the researcher would afford learners the opportunity to increase readability. They would also enable the students to better and more accurately present their knowledge.

Argument mapping

An argument map denotes a diagram comprising "color boxes and arrows" and indicates a claim and claim-evidence relationship (Dwyer, 2011; van Gelder, 2002). In such maps, the color boxes indicate the status of basic claims (black box), reasons (green box), objections (red box), and exceptions ("notes" yellow box), while the arrows reveal the evidence-based relationships between the above features (van Gelder, 2002). Argument maps are generally created by hierarchically arranging the contentions made by a text in the form of a pyramid (Davies, 2011). In this manner, the disclosure of the argument structure enables reasoning (Dwyer et al., 2011). Argument maps allow students to create a discussion structure by visualizing the inferential links between propositions and conflicts (Davies, 2011). As a tool, the argument map actualizes specified points (Uçar, 2018). Students must envision, reconsider, and evaluate their ideas and reasoning through the argumentation process. It was thus postulated that argument maps would allow students to understand and comprehend the structures that constitute the reasoning of ABI practices and enable learners to display a hierarchical structure of the class discussion.

Several argument mapping tools have been developed to facilitate the generation and visualization of contentions through the ameliorated creation, organization, and examination of argument structures (Scheuer et al., 2010). In the course of the present study, students created individual argument maps using paper and pen instead of software used as computer-aided argument mapping tools.

To summarize the above discussion, concept maps represent the verbal expression of concepts and visualize the formation of inter-conceptual relationships while maintaining content integrity; argument maps present means of thinking about a discussion structure within a specific hierarchical structure. The difference in the detail of spoken language denotes a crucial difference between mapping techniques (Davies, 2011). Concept maps encompass a variety of relational structures; hence, the language used is wider. In contrast, in argument maps the lingual relations are limited to the expression of logical conjunctions such as "because," "or," or "however" (Davies, 2011). Table 1 presents the structures of these two mapping methods according to Davies' classification (Davies, 2011, p. 289).

Evaluating the tools distinctively, this study comparatively investigated the impact of the robust mapping methods of generating concept maps and argument maps on students in the same environment. Aligning to the conditions mentioned above, the present investigation aimed to examine the comparative influence of argument maps and concept maps prepared by students on A4 papers on their academic success in learning environments designed on the basis of the ABI approach. Briefly, this study probed the following research questions:

1. How did argument maps and concept maps prepared in addition to ABI applications affect student achievements?
2. How did students view the ABI applications grounded in the extant research and the present investigation?
3. What views did students express vis-à-vis the argument maps generated after the ABI applications?
4. What views did students express vis-à-vis the concept maps created after the ABI applications?

Methods

Model of the research

This study utilized an embedded, mixed-method research design. Such a design employs a fundamental research methodology that directs the study along with a second

Table 1 Structures of concept maps and argument maps

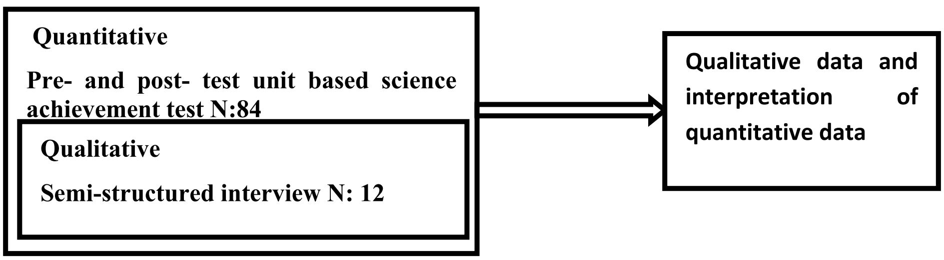
	Concept maps	Argument maps
Purpose	Relations between concepts	Inferences between claims (conclusions) and support (premises)
Structure	Hierarchical, tree-like	Hierarchical, tree-like
Level of abstraction	Medium generality	Low generality
Nodes	Boxes	Boxes and lines
Linking devices	Arrows	Lines, colors, shading
Linking words	Relational phrases ("in relation to," "is composed of," etc.)	Inferential linking words ("because," "not," "however," etc.)
Language register and "granularity"	Medium	Tightly constrained

supportive approach (Smith, 2012). Creswell et al. (2009) stated that this type of design is useful, especially when researchers intend to extend their experimental studies through qualitative data. The quantitative section of this study applied a quasi-experimental design with a pre- and post-test control group. The data for the qualitative aspect of the study were collected via semi-structured interviews and acquired in a manner embedded in the quantitative approach. Therefore, while the study was basically quantitatively directed, the qualitative data offered a supportive and secondary perspective within the scope of the study.

The method and process of this study may be summarized in the following diagram:

Table 2 Study group data

Groups	Application	Number of female students	Number of male students	Total
Treatment 1	ABI + argument map	12	17	29
Treatment 2	ABI + concept map	19	11	30
Control	ABI	14	11	25
Total		45	39	84



Participants

The study group comprised a total of 84 sixth-grade students (45 female, 39 male) of a secondary school in the center of a city in northwest Turkey and affiliated with the Ministry of National Education. The investigation was conducted in the spring term of the academic year 2018–2019 within the scope of the fifth unit of the science curriculum, "Sound and its Properties." Three sixth-grade sections receiving lessons from the same teacher were selected at the secondary school where the study was executed. Two of the selected sections were designated experimental groups (T_1 29 students, T_2 30 students) and the third was nominated as the control group (C 25 students). All three groups undertook research interrogation activities and delivered individual reports based on ABI student templates. Additionally, the first experimental group (T_1) prepared individual argument maps and the second experimental group (T_2) prepared concept maps. Table 2 displays the data related to the study groups.

Data collection tools

The data were collected through an academic success test administered before beginning the unit lessons and that was read ministered after the completion of the unit. The pre- and post-tests were intended to measure academic success and semi-structured interviews were further conducted to ascertain the opinions of students vis-à-vis the applied process.

Academic achievement test

The academic success test was administered as a pre- and post-test to the students to measure their learning within the scope of the stated curricular unit entitled "Sound and its Properties." The test comprised 25 items of 20 multiple-choice and five open-ended questions. A signal table containing a comparison of the targeted behaviors should be created to understand whether each item in the tests is an adequate and appropriate question for the measurement of the defined behaviors (acquisitions) (Büyüköztürk, 2013). Therefore, the academic success test was designed to ensure that questions were homogeneously distributed and included all acquisitions.

The content validity of the test (Balcı, 2004; Karasar, 2004; Çepni, 2014) was examined by experts who included a lecturer, an associate professor, and four science teachers. Necessary changes were made according to the demands of the experts and the test was finalized. The Cronbach's alpha reliability coefficient of the academic success test was found to be 85.

Semi-structured interviews

The study used a semi-structured interview format prepared by the researcher to ascertain the views of participating students vis-à-vis the applied process and to determine how the applications had influenced the students. The interview form included an aggregate of 52 questions, of which the first 27 queried the ABI process, 14 questions asked about the process of creating argument maps and 11 enquired about concept maps. The questions of the interview format were employed as titles during the generation of the principal themes for the findings. The subthemes and categories were listed using specific expressions determined through the word-repetition method. Similar expressions were noted and their frequency of use was specified. A lecturer and two researchers performed this procedure to ensure the reliability of the study. The opinions of students were individually cited to assure the validity of the study.

Application

Before the application was introduced, lessons were imparted in an environment in which the teacher explained the topic and performed experiments as necessary and the students participated as listeners. The delivery of lessons included the use of a smart board and followed the prescribed book or the Education Informatics Network, an online social education platform offered freely by the General Directorate for Novelties and Educational Technologies to every individual. Sometimes, students shared the task of explaining biology topics to their peers via the board. This environment was labeled "Curriculum-Based Teaching" for the purposes of the present study. The unit, "Sound and its Properties," was then taught using the ABI approach. An attention-grabbing preliminary activity was first conducted for the three selected sixth-grade sections to clearly explain to them the process and triangular structure of question-claim-evidence. The students were given a text about a mysterious death and were asked to investigate its cause like detectives. The students made claims by discussing the issue in small groups of 5–6 and supported their claims with evidence that could be gleaned from the provided text. The groups then shared their claims with the whole class. This activity was intended to inculcate awareness and enable students to learn how to make claims and support them with evidence.

After the initial activity, the students conducted a total of five research interrogation exercises conducted over 4 h per week and encompassing the acquisitions expected from the targeted curricular unit. In this 5-week period, the students performed their own experiments and specified appropriate experimental materials they would require to resolve the problems posed by the researcher with respect to each expected acquisition from the unit. They further determined their claims by engaging in small-group discussions in line with the data acquired from their conducted experiments and grounded their claims on evidence. Finally, they shared their claims and evidence with the entire class via full-group discussions.

At the end of each experimental exercise, the students created reports using the ABI student template which incorporated all the stages they had undergone: creating the research question, performing the experiment, making observations and findings, iterating claims, providing evidence, effecting comparisons with their friends and their textbooks, and explaining the changes they had experienced during the process. In addition to the above applications, T_1 was introduced to argument maps at the beginning of the intervention process and the students placed in T_1 were provided due information about how to place the elements (claim, evidence, objection, confutation, and note) that constituted an

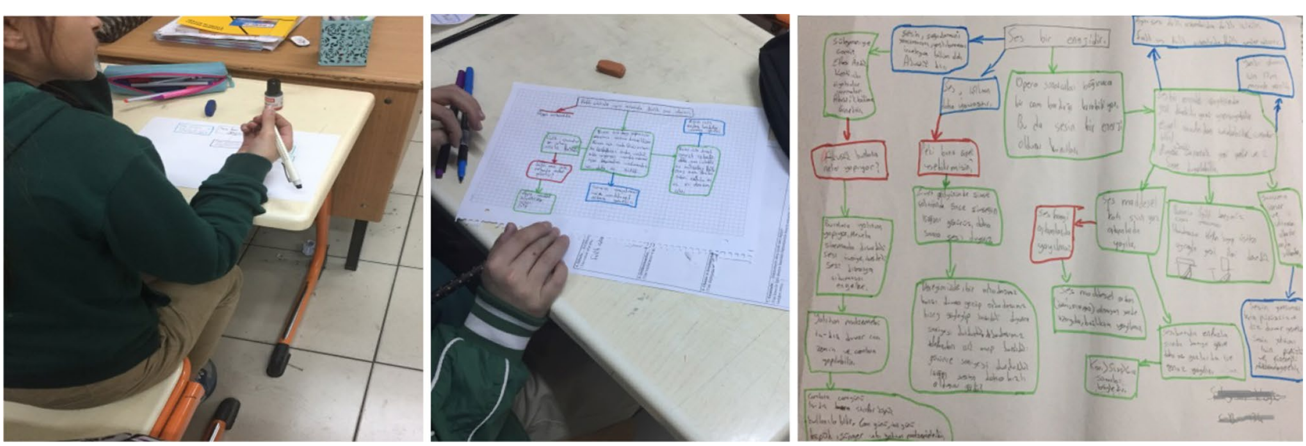


Fig. 1 Sample argument maps

argument map on a page and how to use colors. The T_1 students were asked to prepare individual argument maps after each activity. The students wrote their claims using a black pen, used a green pen to denote facts supporting their claims, employed a red pen to encircle their objections, an orange pen to designate confutations, and a yellow pen to represent notes. The students also created end-of-unit argument maps incorporating all acquisitions, generating an aggregate of five argument maps. Figure 1 presents samples of the argument maps created by students throughout the process.

In addition to the ABI applications described above, T_2 students individually created concept maps after each application. At the beginning of the process, a preliminary session was conducted with the students to introduce them to concept maps. The students placed in T_2 were provided due information about how to place the elements (connection, cross-connection, hierarchy, examples) that constituted a concept map on a page. Subsequently, each T_2 student generated a concept map after every unit activity. The T_2 students also created end-of-unit concept maps that encompassed all acquisitions attained from the intervention. Hence, T_2 students generated a total of five concept maps during the process. Figure 2 displays samples of concept maps created by the students throughout the process.

Data analysis

Analysis of quantitative data

The pre- and post-test scores of participating students were taken into account to measure individual academic success and were assessed through the SPSS software package. A one-way analysis of variance (ANOVA) was performed on the data at the beginning of the study to determine any between-group differences in terms of unit-based success. In addition, the means and standard deviations of the total scores obtained by the students in the academic success pre-test were also separately computed for multiple-choice questions, open-ended questions, and the full test. An analysis of covariance (ANCOVA) was applied to compare the scores obtained by the students placed in the experimental and control groups. ANCOVA is intended to statistically control a factor whose impact is tested in a study or to regulate outside factors and a variable or variables that is/are associated with the dependent variable (Büyüköztürk et al., 2013). The use of ANCOVA offered greater statistical power because of the reduction of error variance and the mitigation of experimental bias in case of between-group differences at the beginning of the experiment (Pallant, 2003).

Analysis of qualitative data

Descriptive analysis was deployed for the analysis of the qualitative data obtained through semi-structured interviews conducted at the end of the experimental intervention with a total of 12 students, four from each of the three groups: T_1, T_2, and C. The names of the interviewed students were coded as $S1$, $S2$, $S3$… and data pertaining to their views were shared with due consideration of the rules of ethical conduct. The interviews conducted with the students were recorded on a tape recorder and were subsequently transcribed and assessed. Once all groups had been evaluated, the principal themes pertaining to the ABI were created: the ABI process, making reports, and assessing the method. Evaluations of data obtained from T_1 students also included the argument map theme; similarly, the concept map theme was added to assessments of data obtained from T_2 students. Analyses were performed to determine the activities in which the students participated throughout the process, the manner in which they conducted group activities, the tasks assumed by teachers during the experimental process, and how the intervention had changed the students.

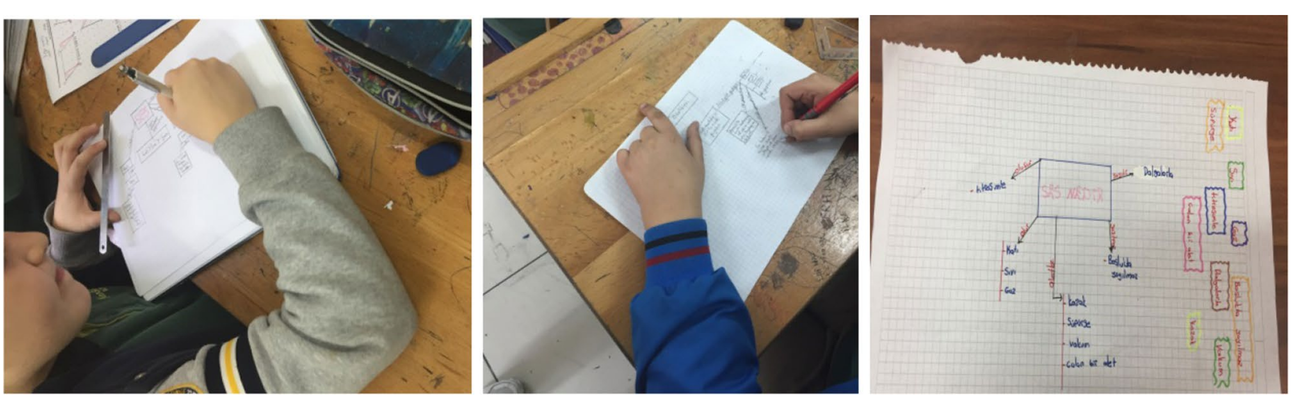


Fig. 2 Sample concept maps

Findings

Quantitative findings

Findings related to the analysis of the academic success pre-test

A one-way ANOVA was applied to the data obtained at the beginning of the study to determine the existence of any inter-group differences in terms of unit-based success. The least significant difference Post Hoc test was deployed to determine the group was supported by a significant difference. The mean and standard deviations of the total scores obtained by the students in the academic success pre-test computed in terms of multiple-choice questions, open-ended questions, and the full test are presented in Table 3. The ANOVA results are exhibited in Table 4.

Table 3 Findings related to the academic achievement pre-test of the students

Pre-test	Application groups	*N*	*X*	*SS*
MCQTS	T_1	29	19.24	6.53
	T_2	30	21.20	8.66
	C	25	21.24	8.95
OEQTS	T_1	29	3.96	3.78
	T_2	29	7.27	4.66
	C	24	5.95	6.27
TTS	T_1	29	23.20	8.48
	T_2	29	29.20	11.33
	C	24	28.08	12.19

MCQTS, total score of multiple-choice questions, *OEQTS* total score of open-ended questions, *TTS* test total score

A one-way ANOVA was performed to determine whether a significant difference existed among the three groups. Table 4 displays the ANOVA test outcomes. The data analysis determined no statistically significant difference among the groups in terms of their academic success at the significance level of $p < .05$ in the overall test scores ($F_{(2, 81)} = 2.545$, $p = .085$) and the total scores of multiple-choice questions ($F_{(2, 83)} = 0.567$, $p = .569$). However, a statistically significant difference was obtained on the total scores of the open-ended questions ($F_{(2, 81)} = 3.316$, $p = .041$). This significance was found to be on behalf of T_1 in the comparison between students placed in the T_1 and T_2 groups.

Findings related to the post-test analysis of academic success

As noted above, the analysis of the pre-test results of the academic success test revealed no statistically significant difference in terms of the total test scores and the total scores of the multiple-choice questions but a statistically significant difference was noted in the total scores of the open-ended questions. The ANCOVA analysis was applied to eliminate these differences. The ANCOVA in which the pre-test is controlled as a common variable is the most appropriate statistical procedure for a pre- and post-test design that includes a control group and focuses on determining the efficacy of an experimental method (Büyüköztürk et al., 2013). The scores obtained by each group on the pre-test were used as the common variable. In performing the analysis, total scores of the multiple-choice questions, the total scores of the open-ended questions, and the total test scores were individually examined. Table 5 outlines the sample sizes, mean scores, and corrected mean scores of the three groups. Table 6 overviews the findings of the ANCOVA analysis.

Table 4 Pre-test academic success one-way ANOVA findings

	Total of squares	Degree of freedom	Average squares	*F*	*p*
MCQTS					
Between-groups	74.223	2	37.111	0.567	.569
In-group	5298.670	81	65.416		
Total	5372.893	83			
OEQTS					
Between-groups	160.832	2	80.416	3.316	.041
In-group	1915.717	79	24.250		
Total	2076.549	81			
TTS					
Between-groups	581.771	2	290.886	2.545	.085
In-group	9029.351	79	114.296		
Total	9611.122	81			

Table 5 Post-test academic achievement findings

Post-test	Application groups	N	Average	Adjusted average
MCQTS	T_1	29	36.20	37.30
	T_2	30	31.00	30.44
	C	25	33.00	32.40
OEQTS	T_1	29	15.62	16.97
	T_2	29	15.66	14.56
	C	23	10.83	10.51
TTS	T_1	29	51.83	56.22
	T_2	29	47.10	44.70
	C	23	45.00	42.49
OEQ-2	T_1	29	2.69	2.95
	T_2	29	2.60	2.48
	C	23	1.73	1.59
OEQ-4	T_1	29	2.38	2.37
	T_2	29	3.14	3.15
	C	23	1.26	1.25

The findings outlined in Table 4 evinced no significant difference in the corrected total scores of the students on the post-test multiple-choice questions in comparison to their total scores on the pre-test multiple-choice questions ($F_{(1,80)}=2.527$, $p=.086$, $\eta p^2=.059$). However, a significant difference was found in the corrected post-test total scores of the students on the open-ended questions in comparison to their total scores on the pre-test open-ended questions ($F_{(1,77)}=5.154$, $p=.008$, $\eta p^2=.118$). These significant differences were found to favor the T_1 group in the comparison between the T_1 group students ($M=3.96$, $SD=3.78$) and the control group students ($M=5.95$, $SD=6.27$). Similarly, the differences were noted to benefit the T_2 group in the comparison effected between the T_2 group students ($M=7.27$, $SD=4.66$) and control group students ($M=5.95$, $SD=6.27$). In addition, a significant difference was found between the corrected total scores on the post-test vis-à-vis the total pre-test scores ($F_{(1,77)}=5.077$, $p=.008$, $\eta p^2=.116$). In the comparison of the scores obtained by students placed in T_1 ($M=15.62$, $SD=7.15$) and T_2 ($M=15.46$, $SD=9.00$), these significant differences were found to favor the T_1 group. The comparison of scores attained by students in T_1 ($M=15.62$, $SD=7.15$) and the control group ($M=10.79$, $SD=7.18$), similarly revealed that the differences benefited the T_1 group. In this instance, the values calculated by the statistics program were partial eta square (ηp^2) and variance rates that can be explained through divergences when other variables are excluded. An examination of the ηp^2 according to the total post-test scores of the open-ended questions disclosed that the utilization of argument maps by T_1 after the ABI applications explained 11.8% of the variability from the control group in the total scores

Table 6 Post-test academic achievement one-way ANCOVA findings

Question type	Source of variance	Total of squares	SD	Average of squares	F	p	ηp^2
MCQTS	Pre-test	3814.162	1	3814.162	26.722	.000	.250
	Group	721.321	2	360.661	2.527	.086	.059
	Error	11,418.60	80	142.732			
	Total	109,305.0	84				
OEQTS	Pre-test	1022.896	1	1022.896	20.094	.000	.207
	Group	524.710	2	262.355	5.154	.008	.118
	Error	3919.788	77	50.906			
	Total	21,822.00	81				
TTS	Pre-test	10,495.01	1	10,495.01	38.841	.000	.335
	Group	2743.436	2	1371.718	5.077	.008	.116
	Error	20,805.82	77	270.205			
	Total	220,116.0	81				
OEQ-2	Pre-test	41.438	1	41.438	11.222	.001	.122
	Group	24.824	2	12.412	3.361	.040	.077
	Error	299.084	81	3.257			
	Total	711.000	85				
OEQ-4	Pre-test	3.768	1	3.768	8.17	.369	.011
	Group	46.302	2	23.1510	5.022	.009	.115
	Error	354.943	77	4.610			
	Total	845.000	81				

MCQTS total score of multiple-choice questions, *OEQTS* total score of open-ended questions, *TTS* test total score, *OEQ* open-ended questions of the post-test open-ended questions independently from the pre-test variable of open-ended questions. It was determined that the total scores of the experimental group students on open-ended questions were higher than the scores obtained by the control group students. In addition, examining the ηp^2 according to the total post-test scores revealed that the utilization of argument maps by T_1 after the ABI applications explained 11.6% of the variability in comparison to the T_2 group and control group in the overall total scores of the post-test independently from the pre-test total variable. It was thus determined that the total test scores of the students grouped in T_1 were higher than the scores of the students placed in T_2 and in the control group.

Qualitative findings

As described above, semi-structured interviews were conducted with a selection of the participating students. The data analysis yielded themes related to the ABI applications, argument maps, and concept maps. The codes for each theme and the frequencies relating to the codes are provided in the tables below.

Analysis of student opinions on ABI practices

The data related to the ABI applications were evaluated according to the subthemes of analyses aimed at the application, at report-creation, and at methodology assessment. Table 7 presents the frequencies of subthemes and codes

Table 7 Themes, codes, and frequencies resulting from the evaluation of student opinions on ABI applications

Theme	Subthemes	Codes	Frequencies
Process/application	Preparing for the lesson		12
	Claim	Creating	8
		Strain	7
	Features of the claim	To be provable	6
		Relevance to the subject/question	3
		Should be short	2
		Should be clear	2
	To decide	Group by	12
	Contradictory situations in small groups		12
	Resources	Internet	6
		Book/books	5
		Teacher	1
	Large group discussion	Helpful	12
		Instructive	10
		Supporting/not supporting	9
		Enjoyable	8
		Asking questions	6
		Critiquing	5
	Student roles	Experimenting	7
		Making claims	6
		Peer-education	6
		Acquiring the requisite knowledge	3
	Teacher roles	Providing hints	9
		Offering directions	8
		Asking questions	7
		Making suggestions	5
	Comparing the information in the source	Multiple source scans	6
		Comparison between books	5
		Comparison of information obtained from websites	5
		Comparing book and Internet-based information	4
	Writing a report	Contributing to learning	9
		Parallel to the lesson	6
		Strain	4

revealed from the examination of the views expressed by students on the applications.

The students primarily introduced the lesson process during the semi-structured interviews conducted with the students. They indicated that they performed experiments and made claims during the experimental process. The students stated that they would pay particular attention in making their claims to ensure that they were provable, explicit, clear, short, and convenient for the subject/question. The student coded S_{11} said, "…we considered its convenience for the subject…." S_5 asserted that.

> …when making a claim, you need to keep away from repeating the question. The claim should be explicit, clear and short. There is no need to write and explain it in detail. If you do that, they will understand your purpose and try to confute it…

S_2 emphasized the properties of a claim, stating:

> When making our claim, we paid a particular attention so that it would be provable. It is because we would support it with our experiment. We were going to tell about the experiment in the presentation. That's why the claim had to be provable…

In addition, the interviewed students iterated that they found it difficult to make a claim. All the students indicated that worked as a group to make decisions at the stage of uncertainty and thus experienced contradictory situations from time to time. S_6 stressed this situation as follows:

> …Our friends are unable to arrive at a consensus when making a claim. For example; one wishes this and the other one wishes that. Then everyone writes it down on a page and we try to choose the best one as a group. However, we eventually end up making a claim…

Also, the students who underwent the process stated later that they found it difficult to make a claim and were better able to perform this task over the course of time. For example, S_3 said:

> …I had no idea about the process at the beginning of the class. When we chose it with our friends, there was nothing in my mind. But as we did experiments, my horizon opened up and I made a progress…

The students were asked to compare the full-class and small-group discussions they experienced via the ABI. Most participants stated that they found the full-group discussions more useful, instructive, and enjoyable. The students indicated that the groups would sometimes support each other in the full-class discussions and sometimes they had to deal with contradictions. They also specified that they would ask questions and offer criticism. For example, S_5 articulated the situation in the following manner:

> It is better for me to work in big groups. We get the opinions of our friends both in big and small groups. We also get the opinions of other groups and the teacher. We obtain more information with the opinions of others, which is more fun and instructive.

All participating students indicated that preparation was required before the class for the ABI process to be effective. They further stated that they prepared for the classroom lessons by reviewing the literature and comparing the information obtained from the review. An interview episode reflecting this situation is reproduced below:

> *R*: Had you made any preparations before you came to the class?
> S_6: Yes. For example; I had no idea about the new subject, which was about whether the sound would spread in space or not. I had investigated it.
> *R*: How did you investigate it?
> S_6: On the internet.
> *R*: But there are too much information on the internet. How did you manage to find the right information?
> S_6: We consulted our teachers after searching the internet.
> *R*: Did you get information from only one website?
> S_6: No. I got information from more than one websites and compared this information. I also got information from the books and compared them with the ones from the websites.

In the semi-structured interviews, the students specified that the ABI approach exerted a positive impact on them and explained the roles of students in the classroom from many to few: perform an experiment, make a claim, undertake peer-education, and learn the knowledge. Some examples of student statements reflecting the effects of ABI are noted below:

> S_{11}: "We usually learn such kind of knowledge. When the teacher is like a resource, we learn it…".
> S_{10}: "Learn something… We created our experiments, distributed the tasks within the group and made our claims…".
> S_9: "…Do an experiment, support the opinions of my friends, assist in the claims, divide the materials as a group…".
> S_6: "Make a claim, receive the opinions of my friends, respect the opinions of my friends, do an experiment."

During the interviews, the students also mentioned the roles discharged by the teacher, stressing that the teacher helped the students manage the process by offering them clues rather than direct information. In addition, they asserted that the teacher guided the students, helped them discover the truth by asking questions when necessary, and offered opinions to the group only when the students were totally uncertain. Some examples of student statements reflecting their views on the teacher's roles are provided below.

> S_{10}: "…When we were fewer in number or there were discussions in the group, the teacher would help us find better claims and do the experiments better. She/he would guide us and give us clues about what kind of path we needed to follow…".
> S_7: "…The teacher would help us. She/he would give us clues based on our thoughts…".
> S_{11}: " …First she/he would listen to us. Then she/he would praise our experiment if it was indeed good. She/he would give us opinions to develop it a little further…".
> S_9: "…She/he would visit the groups and ask us questions about our claims and what we would do…".

The students completed the ABI reports that required them to reflect on the process and submitted them to the researcher at the end of every activity through the course of the ABI intervention.

The students particularly denoted that the creation of a report, which formed a dimension of ABI, occurred parallelly with the lesson. The act of writing reports restricted them but also contributed to their learning. The students stated that the writing of reports compelled them to reflect, especially the sections arousing awareness (my thoughts at the beginning? and Reflection?). S_5 described the situation as "some of my thoughts at the beginning were similar with my thoughts at the end. Indeed, I had a little difficulty at that point. I wondered if I had to change it or not." S_3 expressed the advantages of writing reports by saying, "Making a report is kind of like summarizing. By this way we will know to what extent we have learned and comprehended that lesson."; S_{11} said:

> Making a report has taught me knowledge and entertained me. It is fun. I think we should do it every year. I also think that we had to begin to write reports in the fifth grade. We mainly learn when we do an experiment and make a report. Then we get more information when the teacher summarizes. We learn the subject better.

Table 8 Themes, codes, and frequencies for the evaluation of ABI applications

Theme	Codes		Frequencies
Methodology assessment	Enjoyable		7
	Instructive		6
	Choice	ABI applications	12
		Curriculum-based	0
	Applicable	Science lesson	7
		Math lesson	4
		Turkish lesson	2

The students were also asked to assess the methodology during the interviews. The themes, codes, and frequencies created from the assessment of their explanations are exhibited in Table 8.

The students assessed the ABI methodology as enjoyable and emphasized that ABI could be applied to various subjects and not merely science lessons. S_6 indicated that learning via this method was instructive and pleasurable:

> We have fun when we do experiments. Even if we don't do experiments for a long time, the lesson is still fun. We have fun with our teachers. We learn more with experiments. We learn the things we are curious about.

In terms of preference, S_3 opined that lessons using this methodology should be sustained:

> I would rather the lessons be taught via this method. It is because we used to listen, take notes and follow the subjects in previous classes. I think doing experiments, following, teaching the subjects and writing on the board will be more useful…

S_9 stressed that this pedagogy may also be applied to other subjects: "…I would like to learn my other lessons via this method as well. It may enable me to understand the subjects better. I still understand them, but this way it may be better."

Analysis of student views on argument maps

Semi-structured interviews were conducted with four randomly chosen students from the T_1 group, which created argument maps after every ABI activity. Table 9 presents the themes, codes, and code-related frequencies generated from the analysis of their interview data.

Argument maps comprise varied elements and are created using arrows, colors, and boxes. These boxes contain structures such as claims, supports, confuting, notes, and objections expressed by different color codes. During the interviews, the students underlined that they were aware of the structures when they made the argument maps. They iterated that argument maps could not be created without "components, information reinforcement, and correlation codes." S_3 stated:

> An argument map has to contain a claim, support, confuting, note and an objection. Or else we will have a difficulty reinforcing the information. It is important for us to establish relationships in order to create an argument map.

Table 9 Themes, codes, and frequencies related to argument maps

Theme	Codes		Frequencies
Implementation of the argument map	Creating properties	Claim	4
		Support	3
		Rebuttal	3
		Objection	3
		Note	3
	Knowing the meanings of colors		4
	Difficulties in creating argument maps		3
	The constituents of the argument map	Components	3
		Relationship	3
		Strengthening knowledge	2
Contribution of argument maps to the individual	Learning		4
	Awareness		3
Comparison of argument maps	Time preference in use	At the beginning of the lesson	0
		During the lesson	0
		At the end of the lesson	4
	Change in the first and last argument maps	Creating multiple components	3
		increase in the number of boxes	2

The interviewed students asserted that the making of argument maps contributed to their learning and enabled them to note their deficiencies and pay more attention to their next maps. For example, S_3 said:

> Argument maps have contributed to my learning, in terms of verbal and formal expression. I tried to understand at which point my claim had begun to confute and how I could get better support. When I did this, I realized that I needed to be more careful in the next experiments. I realized my deficiencies in the experiments and understood what I had to regard in the next experiments.

Similarly, S_6 stated:

> They have contributed to my learning. It is because when preparing the maps, we had been through stages supporting, confuting our claim and we needed to take notes related to our claim. I can understand this better as I specified it in the argument map.

Despite the above advantages, most of the interviewed students indicated that they found it difficult to create argument maps, primarily for two reasons: first, it was difficult for them to become accustomed to the process in the initial phase; second, they fell behind in creating argument maps when they were unable to design their experiments. S_5 explained this situation as follows:

> …at first I had a difficulty, because we had never done this before. Then I had a greater difficulty because there was nothing to tell when we were not doing experiments. Not doing experiments prevented me from creating an argument map.

During the 5-week ABI intervention, the students created their argument maps at the final stage of every lesson. The students also evinced their preference for the final stage when they were asked during the interviews, “At what stage of the lesson would you like to use the argument map if the process in the application was rearranged?” S_2 iterated,

> …if we do it at the beginning, we won’t succeed it. If we do it in the middle, we will have nothing but our claim, because we are inexperienced. If we do it at the end, we will know what is wrong and right or our deficiencies…

S_3 underscored the need to generate argument maps before reporting.

> I think it should have been done before reporting. It is because we would be able to reveal our work, experiments and supports better on argument maps. Therefore, it might have been easier if we had created our reports.

In addition, when the students compared their first and last argument maps to determine the changes on the maps, they indicated that the number of components and boxes had increased. They also highlighted that they had learned the process. S_7 asserted:

> There is a great difference. It is because when we created the argument map for the first time, I could finish

Table 10 Themes, codes, and frequencies related to concept maps

Theme	Codes		Frequencies
Execution of concept maps	Identifying concepts		3
	Creating focus concept		3
	Establishing a relationship between concepts		3
	Difficulties in establishing relationships between concepts		2
Knowing the features of the concept map	Forming sentences		3
	Relationship determination		3
	Choosing the right concept		3
	No visual complexity		1
Contribution of concept maps to the individual	Contributing to learning		4
	Improving thinking		2
	Being able to express yourself		1
Comparison of concept maps to the course and methodology	Comparison with the ABI process	ABI	3
		Concept map	3
	Time preference in use	At the beginning of the lesson	0
		During the lesson	0
		At the end of the lesson	4
	First and last concept map comparison	Increasing concept	3
		Increasing relationship	3
	Applicability to all courses	Science lesson	4
		Turkish lesson	2
		Math lesson	2

> it with fewer boxes. However; as I did it constantly, my page would be full toward the end. I created more reasons and objections.

Analysis of student views on concept maps

Semi-structured interviews were conducted with four randomly selected students from the T_2 group, which created concept maps after the ABI applications. The students' opinions about the concept maps were assessed. The themes, codes, and code-related frequencies obtained from the analysis of their interview data are outlined in Table 10.

During the interviews, the students stressed the importance of primarily determining the concepts, creating a focal concept, and establishing inter-conceptual relationships when creating concept maps. S_1 said, "…at first I would write down the things we did on a page. Then I would choose appropriate words on the page and start creating my map by choosing the concepts." S_9 stated:

> …I would choose the most stunning word regarding the subject for the focal word… It is because unless we know what the concept is associated with, we will not succeed… I had been thinking about what I could write on the arrow. For example; I associated the statement "the sound spreads in waves," with the arrow."

These statements emphasized the importance of the varied stages. The interviewed students also underlined the difficulty of establishing inter-conceptual relationships. S_{11} asserted that the students found it difficult to establish inter-conceptual relationships when creating concept maps because the process was new to them:

> …at first I understood nothing. I kept telling myself that I wouldn't be able do it. But then I grew accustomed to it. It is better and more fun when we combine the concepts. When I did it for the first time, I got help from you. But then I began to do it without help as I continued.

During the semi-structured interviews, the researcher asked the students "What do you think are the property/properties of a good concept map?" The students offered the following answers: make a good sentence, determine inter-conceptual relationships, choose the right concept, and avoid the selection of visually complex concepts. The student views on this matter are reproduced below:

> S_1: "I checked whether my words were appropriate or not. I checked the relationship between my words and established relationships."

> S_4: "Choose appropriate words for the subject, establish relationships properly and avoid choosing visually complex concepts."
> S_9: "Choose concepts related to the subject that may associate the things they tell in a good and meaningful way."
> S_{11}: "…there should be words and the verbs on the arrows should be good. I mean the statements should be good."

The students indicated that the act of creating concept maps contributed to their learning and individual development. S_9 asserted:

> …it has contributed to my learning. It is because we did it right after presenting the subject. As we did concept maps and experiments, it was more permanent. However, concept maps make our memory more permanent. I mean I have learned how to associate a situation. I have learned how to associate my thoughts. It allows me to think strongly.

S_4 claimed, "It has contributed to my learning. Also it allows me to express myself. I am now able to make better sentences."

A sample dialog reflecting the researcher's attempt to determine the impact of the act of creating a concept map after teaching the students the lessons via the ABI approach.

> *R*: "Did the teaching of the lesson in line with the ABI approach (making a claim, doing an experiment, doing big and small-group discussions, creating reports) contribute to you to create the concept map?".
> S_9: "Yes, it did. You learn via concept maps. You learn a lot. You learn when you do an experiment, create a concept map and make a report. It was more fun. Making a report, creating a concept map and doing an experiment were like activities performed in the classroom. It was really nice. In addition, as we learn the subject via experiments, we actually find the words ourselves and the concept map is created with what we have created. Therefore we learn the subject better."

During the 5-week intervention, the students created the concept maps at the final stage of every activity. The students stated a preference for the final stage when they were asked: "At what stage of the lesson would you like to use the concept map if the process in the application was rearranged?" The student views on this matter are presented below:

> S_{11}: "If we had done it at the beginning, I think it would not have been successful. We needed to learn first. When we used the knowledge acquired from the experiment in the concept map, it turned out to be a success. Our experience on the experiment helped us remember our words."
> S_9: "I still believe that it should be prepared in the final stage. It is because it enabled us to create permanent discussions in our mind, remember the words and establish a relationship with the words. We directly wrote the words on the concept map and associated the words that remained in our mind."

As the students grew accustomed to the process, they revealed some developments in their concept maps. S_6 indicated that the number of concepts and inter-conceptual relationships evinced a marked increase toward the end of the 5-week intervention:

> …I went into the details of the concept map. At first I would write in really small fonts. But then I managed to magnify the map further. While I used fewer concepts at the beginning, I used more concepts at the end. More concepts means more relationships.

Discussion and conclusion

This 5-week study was conducted with three sections of grade six students of a secondary school during science lessons imparting the curricular unit titled "Sound and its Properties." It applied the ABI approach, which is grounded on research interrogation and required the students to undertake activities in small groups that demanded specific abilities such as hand skills to be developed in them. The study comprised three groups: one section that was designated the control unit and two experimental groups labeled T_1 and T_2. The control unit performed only the ABI exercises. T_1 was tasked with creating argument maps on A4 papers using paper and pencil after every ABI application, while T_2 was asked to similarly generate concept maps on A4 papers after each ABI activity. The study was conducted to examine whether a significant difference could be found between the three groups in terms of their academic success in the test administered to them before and after the designated topics were delivered via the ABI approach. The results confirmed that the generation of argument and concept maps by the experimental groups ameliorated their academic achievement in comparison to the control group.

The three groups were established for this study from three separate sections of the sixth-grade of the school instructed by the same teacher. The examination of their results was based on the pre- and post-administration of the academic achievement test for the curricular unit that was imparted via the ABI approach. No difference was observed among the groups vis-à-vis the overall scores of the pre- and post-test multiple-choice questions. However, compared to total scores obtained on the pre-test open-ended questions, a significant difference was noted in the students' total scores of the corrected post-test open-ended questions. Comparing the control and experimental groups, this difference was significant in favor of the experimental groups. The unit test items requiring open-ended answers focus on the student's skill of perceiving, justifying, and utilizing the imbibed knowledge (Badger & Thomas, 1992). Cooney et al. (2004) have reported that students learn in different ways and display their knowledge and ideas using varied methods. A test comprising open-ended items affords students the opportunity to showcase learning. Bahar et al. (2012) have also asserted that high-level skills are better measured via open-ended items than through multiple-choice questions. Open-ended items urge students to think multi-directionally and creatively and encourage them to approach events from different points of view (Akay et al., 2006). Thus, the current study included open-ended questions in the unit success test taking the above points into account. Consequently, the evaluation of the total pre-test scores and total corrected post-test scores obtained by the grouped students on the academic achievement test yielded a significant advantage for T_1.

Semi-structured interviews were conducted with selected students from each group after the completion of the experimental intervention. The interviews sought the opinions of the control and experimental groups regarding the process they had undergone. Members of the three groups were asked questions about their evaluation of the ABI process and expressed views such as they could learn science better through the ABI process, the classes were more productive, they spent more time thinking about the subjects via experiments, enjoyed performing experiments, and were able to learn as they attempted to discover answers to questions requiring reasoning. They also specified that they could make claims on the basis of the evaluation of its properties. The students asserted that compared to the beginning of the intervention, they could formulate better claims toward the end of the process. The students also displayed an awareness of the tasks to be discharged by their teacher and by themselves during the ABI applications. The interviewed students also evaluated the science lessons taught according to the ABI approach vis-à-vis the traditional curriculum-based approach and indicated the differences between the pedagogic methodologies: performing experiments, conducting writing activities, and participating in individual as well as group studies.

Several studies have suggested that the ABI approach is effective for science lessons and can help students in ameliorating their comprehension of scientific concepts (Çakan et al. 2019; Günel et al., 2010; Hand et al., 2004; Kabataş Memiş, & Ezberci Çevik, 2016; Kabataş Memiş & Seven, 2015; Kaya & Kılıç, 2010; Kıngır, 2011; Kıngır et al., 2012; Yaman, 2011). The ABI requires students to think during the learning process, to establish relationships between the data, to interpret the data, to make connections between claims and evidence, and to explain their results. All these activities develop high-level thinking skills in students (Kabataş Memiş, 2011). The ABI can exert these effects on its own; however, better outcomes can be obtained when this pedagogy is supplemented by extra writing activities. The present study tested this postulation by employing the variable of generating paper and pencil argument maps and concept maps in addition to the ABI applications.

Students develop a more profound conceptual apprehension of topics through ABI applications by establishing a correlation between the research question, observations, data, claims, evidence, and projection phases that form the elements of a scientific argument (Choi et al., 2010). ABI allows students to experience the argumentation process and helps them strengthen their theoretical understanding (Akkuş et al., 2007). The active participation of students in discussions and in argumentation processes through inquiry-based scientific research enables the development of a more profound conceptual understanding (Kabataş Memiş & Çakan Akkaş, 2020; Nam et al., 2011). Students are thus prepared for meaningful learning through conceptual knowledge. Mapping methods enable learning by placing knowledge in the form of a visual diagram and thus help students actualize meaningful learning (Canas et al., 2005). Mapping visualizes knowledge and is thus a tool that promotes the meaningful learning process. The visual knowledge that is designed forms both the product and the purpose of the meaningful learning process (Novak & Canas, 2006).

Speaking and writing skills are pivotal to learning (Rivard & Straw, 2000). Speaking is crucial to asking questions, creating premises, explaining hypotheses, gathering opinions, sharing scientific views with peers, clarifying ideas, and engaging in discussions (Rivard & Straw, 2000). Writing is vital for the processing and reinforcement of new opinions through previously attained knowledge (Rivard & Straw, 2000). According to Langer and Applebee (1987), writing enables students to explain and organize their knowledge and to reflect on their learning experiences (Mason & Boscolo, 2000). Writing also allows students to communicate more effectively and helps them think critically and create new knowledge structures (Klein, 1999). In addition to all these aspects, writing contributes to meaningful learning, which occurs in the domain of science through conceptual changes (Mason & Boscolo, 2000). It is thus an important learning activity for science education.

The study required students to generate and deliver their verbal arguments during the ABI activities and to also showcase their written arguments via argument maps. The argument map can be defined as a tool that facilitates the textual and visual presentation of arguments (Çakan Akka et al., 2018; Sönmez et al., 2020; Uçar, 2018). It offers the convenience of creating, organizing, and reading arguments (Dwyer et al., 2010). In brief, the argument map aids in the analysis of argument structures and eases the assessment of the reasoning process (Dwyer et al., 2011; Sönmez et al., 2021). The argumentation process mandates the construction of an argument; it also asks students to review and evaluate the argument for deficiencies (Ford, 2008). The views expressed by the students during the interviews were congruent with these features. The students indicated that argument maps enabled them to read better as they visualized an argument, enhanced their argumentation skills, helped them to think more comprehensively, accorded them with the practice of formulating their arguments, and allowed them to assess their own arguments. The interviewed students also stated that argument mapping helped them to analyze the subject as a whole through imagery. Moreover, the students underlined that argument maps created through writing and coloring helped them remember the topic in question. The group that generated argument maps asserted that they could visualize the class discussion by projecting the ABI process on the map. Thus, they were able to control the discussion structure and could also change it via confutation if necessary. The members of this group also indicated that they could more easily perceive the significant conceptual relationships between the class discussions.

The concept map represents another mapping method vital to the revelation of conceptual associations. The concept map is a learning and teaching strategy that establishes a bond between how students learn and the meaningful learning they acquire (Kaplan, 1998). Concept maps are selected in educational environments because they empower students to understand theoretical ideas, to learn them in a meaningful manner, and to establish associations with the concepts they have previously acquired. Above all, the maps prevent misunderstanding and reduce incomprehensibility. The construction of a concept map to structure correlations, especially between the newly learned concepts, can be considered a creative activity (Gültepe & Kabataş Memiş, 2014). Kaptan and Korkmaz (2001) have defined concept maps as: "They enable students to establish associations from only one unit throughout an academic year or between the concepts in a lesson, to form tangible and visual arrangements in their mind and to schematize these inter-conceptual relationships." (p. 21).

These attributes allow concept maps to be utilized in science pedagogy as a strategy that delivers meaningful learning. Concept maps also develop creative thinking skills in students, including cognition, analysis, and problem-solving. Thus, they enable students to better understand important scientific concepts (Novak et al., 1983). Concept maps serve as a template or landing stage for learners and are thus powerful means of facilitating meaningful learning in students (Cañas & Novak, 2008). During the interviews, the students stated that concept maps played an important role in their learning. According to them, the formulation of concept maps required them to first determine the concepts: they had to initially create the focal idea and were then required to establish relationships between notions. The students also asserted that it was essential for them to form sound sentence structures in concept maps. Moreover, they said they could formulate better sentence structures using concept maps. Thus, the process helped them express themselves better. The interviewed students from the group charged with preparing concept maps emphasized that the combination of the initial ABI activity followed by the task of generating individual concept maps was extremely influential for the recall of the information they had learned.

The present study incorporated the production of argument and concept maps to the ABI intervention. Its results computed through the unit academic achievement test allow the assertion that science learning was ameliorated through ABI and was further improved when ABI was supplemented with these means. In addition, the group that experienced both the ABI application and argument mapping was more successful in the academic achievement test in comparison to the other two sections. Thus, the present study contributes substantially to the extant literature. The students opined that both types of mapping influenced them in a positive manner, raised their awareness, and contributed to their scientific learning and individual development.

Suggestions

Argumentation skills tend to develop over the course of time. This study was conducted in a relatively limited time, during which the participating students received a 4-h training session on the prescribed argument mapping methodology. However, some students found argument mapping a difficult task, perhaps because the 4-h training module was inadequate for some learners. It is thus suggested that long-term studies may be planned in the future to track the development of argumentation skills. Additionally, the literature review performed for this investigation revealed the absence of studies on the utilization of argument maps by secondary school students. Hence, more such studies should be conducted to bridge this gap in the literature. The present study required the participating students to apply computer-aided argument mapping techniques using paper and pencil due to the physical circumstances of the institution at which the ABI intervention was undertaken and the number of participating learners. Taking the number of learners and physical conditions into account, prospective studies could compare the achievements of learners through the use of digital argument maps prepared using computer-based technologies.

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