

The Influences of an Argumentative Discourse Learning Environment on Eighth Graders' Scientific Argumentation Ability

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The purpose of this study was to establish an argumentative discourse learning environment to explore its influences on 8th graders' scientific argumentation ability. A none-equivalent pretest-posttest quasi-experiment design was adopted. The research subjects included the students from two 8th grade classes with one class being the experiment group and the other being the control group. The argumentation teaching was given to the experiment group and the traditional teaching was given to the control group for the period of 30 sessions for the teaching unit "light," followed by "temperature and heat." One-way analysis of covariance (ANCOVA) was applied with the students' sectional exam scores before the teaching was used as the covariate variable and their argumentation ability test scores for the two units after the teaching as the dependent variables. A significant difference in the students' argumentation ability was found with larger effect ($\eta^2 > 0.14$) for the "temperature and heat" unit ($p < 0.05$), but not for the "light" unit ($p > 0.05$), meaning that the students' argumentation abilities could be effectively improved in a longer learning period within this argumentative discourse learning environment.

Keywords: argumentative discourse, argumentation teaching, scientific argumentation ability

Introduction

The focus of science education nowadays is on developing students' argumentative ability (Kuhn, 2010; Osborne, 2010; Ryu & Sandoval, 2015; Sampson & Blanchard, 2012) for at least two reasons: 1. Argumentation is the core activity of scientists, as it is about constructing a reasonable connection between their hypothesis and evidences (Grandy & Duschl, 2007; Lawson, 2003; Newton, Driver, & Osborne, 1999); and 2. Argumentation is one of the important meanings of scientific literacy (Gott & Duggan, 2007; Jiménez-Aleixandre & Erduran, 2008; Organization for Economic Co-operation and Development [OECD], 2003). Because of these two reasons, how to establish a learning environment, which supports students to participate in argumentative discourse in a science classroom, has become an important issue nowadays. There are some common findings in the related studies regarding this issue:

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1. A long-term teaching activity is essential to develop argumentative ability (Kelly & Takao, 2002; Kenyon, Kuhn, & Reiser, 2006; Kuhn & Reiser, 2007; Osborne, Erduran, & Simon, 2004; Zohar & Nemet, 2002);
2. The role played by teachers' scaffolds is crucial (Kenyon, Kuhn, & Reiser, 2006; Kortland, 2001);
3. Argumentative teaching is often integrated with activity designs, teachers' strategies, and classroom atmosphere as supports (Kuhn & Reiser, 2007; Zohar & Nemet, 2002);
4. Students are encouraged to review their understanding, ideas, and standpoint changes (Jiménez-Aleixandre & Pereiro-Muñoz, 2002; Mason, 1996).

Literature Review

From the perspective of the essence of science, science is a process of knowledge construction that includes hypotheses, experiments, and argumentation (National Research Council [NRC], 1996). This view suggests that the authenticity of a knowledge claim should be based on not only observation results, but also the process of argumentation. For this, Toulmin (1958) proposed a model to show that the inference and argumentation patterns involved in the process of constructing science knowledge. Toulmin's argumentation pattern can present the regulations of argumentation through a structural method, and thus, it is helpful for the design and practice of teaching, learning, and evaluation. This argumentation pattern is in the form of "due to (data), because of (reason), according to (theory), and so (conclusion)." Thus, teachers can use it to show their students the structure of argumentation and help them to develop the skills required for argumentation.

Although Toulmin's pattern provides a structure for argumentation and the reasonable regulations for the process of argumentation are useful for the design and practice of argumentative teaching, there are still some problems with implementation (Driver, Newton, & Osborne, 2000), such as:

1. This pattern presents the process of argumentation through a way of decontextualization;
2. This pattern does not present the interactive aspect of a discourse event;
3. The structure of a natural discourse may not be so complete;
4. This pattern can be used to evaluate the structure of argumentation, but cannot be used to determine whether the argumentation is correct.

In response to these issues, this study proposed the following teaching strategies and activities:

1. In a classroom, the argumentation process must be performed with a specific context, such as using students' alternative conception as the competition theory to induce the argumentation process (Osborne, Erduran, & Simon, 2004);
2. In a science classroom, students can learn argumentation through interactive discourse, such as group discussion, class discussion, and group discussion evaluation (Erduran, Simon, & Osborne, 2004);
3. In an interactive discourse, it is essential for the teacher to guide his/her students to generate a lot of conversations to form the argumentation process;
4. To determine whether argumentation is correct, the science knowledge involved must be considered and evaluated as well.

Osborne, Erduran, and Simon (2004) supported the idea of using Toulmin's (1958) argumentation pattern in classrooms, yet they took the perspective of changing the pattern of classroom discussions and proposed a way to improve students' argumentation ability. They believed that the first thing to do is to change the epistemological and social structures of classrooms. Regarding the epistemological structure, Osborne, Erduran, and Simon (2004) indicated that the pre-condition of starting argumentation was to create differences. The

focus here is on the alternative theory of the phenomenon being studied. Students are requested to think about more than just one theory for the phenomenon. They must spend time considering the alternative theory. As for the social structure, the main purpose is to facilitate interactions and discourse between/among students. The teaching strategy proposed by Osborne, Erduran, and Simon (2004) was to present or create competing theories for students to discuss in groups. They must evaluate the evidences to support or not to support each theory and defend the theory they support or rebut the other theory through argumentation. Because related resources and data were essential to constructing argumentation, when Osborne, Erduran, and Simon (2004) presented competing theories to their students, they often provided some evidences and asked their students to select appropriate evidences to decide whether they were going to support theory 1, theory 2, both of them, or none of them. Osborne, Erduran, and Simon's (2004) claim of facilitating students' argumentative discourse by creating difference and presenting competing theories was an important reference for the teaching strategy regarding a learning environment to facilitate argumentative discourse proposed by this study.

In summary, designing a learning environment suitable for argumentative discourse is important for improving students' argumentative ability. Thus, this study aimed to build an argumentative discourse learning environment for 8th grade students and explore the influences on their argumentative ability.

Research Design

This study adopted the non-randomized control group pretest-posttest design with two classes of 8th grade students in a junior high school. The independent variable was "teaching method," as the argumentative discourse teaching method was applied to the experimental group and the general teaching method to the control group. The two groups were taught by the same teacher. The dependent variable to be studied was the students' "argumentative ability performance." The teaching duration was six weeks with five sessions per week and 30 sessions in total. The teaching time schedule was the same for the two groups. The teaching content included two science units—"light" and "temperature and heat." One week after the teaching of each unit was completed and a 50-minute argumentative ability test for the unit was conducted. To make sure the science learning achievements of the students before the teaching would not influence the examination of their argumentative ability after the teaching, this study used the first sectional science exam scores before the teaching as the covariate variable for analysis of covariance (ANCOVA). This way, the effect of the science learning achievements of the students before the teaching on the argumentative ability after the teaching could be removed.

Subjects

The research subjects were two classes of 8th grade students in a junior high school. One of the classes was randomly selected as the experiment group (35 students) and the other was the control group (35 students). Because normal class grouping was adopted by the school based on the students' entrance exam scores, the distributions of the quality of the students of the two classes were similar.

Treatment

The teaching for the experiment group covered two units—"light" and "temperature and heat." According to the section order of the units in the textbook, the fundamental knowledge of these units was taught to the students in the experiment group. Related experiments were performed in accordance with the experiment activities of these units. The teaching method regarding this part for the control group was the same. The

purpose of this part for the experiment group was to make sure the students would be able to carry out argumentation based on the fundamental knowledge and experiment data. Then, the experiment group participated in the argumentative discourse learning activities. The control group had to practice problem-solving using the exercises and test papers from the textbook and the teacher would explain the solutions for the group.

The argumentative discourse learning activities for the experiment group included: (a) studying the teaching material with examples based on Toulmin's (1958) argumentative pattern and structure; (b) argumentation based on their alternative conceptions; and (c) argumentative discourse based on the competition theory from students' alternative conceptions.

The teaching strategies applied included: (a) guiding students to make reasonable argumentation using the teacher's demonstrations and hints; (b) asking open questions to allow students to come up with thorough explanation, defenses, and introspections, such as "Is there any evidence backing your idea?" "Why can this evidence back your idea?" and "How do you convince others regarding this idea?" to bring out argumentative discourse of the group and the class; and (c) driving argumentative discourse using "group discussions" and "class discussions" to help students identify differences between two arguments, so that they can defend their theory or rebut the other.

Instrument

The argumentation ability tests in this study were designed based on the main concepts of the units "light" and "temperature and heat" in the 8th grade natural science textbook. The test for the unit "light" contained three questions based on three main concepts: "reflection of light," "imaging with a plane mirror," and "imaging with a convex," respectively. The test for the unit "temperature and heat" contained three questions based on three main concepts: "thermal equilibrium," "heat and temperature changes," and "thermal expansion and contraction," respectively. The structure of these two tests allowed the students to decide whether to support or rebut the competition theory and come up with reasons. The format of these argumentation ability tests conformed to the view of Osborne, Erduran, and Simon (2004) and Kuhn (2005) of inducing students' argumentative discourse using the competition theory from students' alternative conceptions, while the parts of the tests to be answered conformed to the argumentative pattern proposed by Toulmin (1958) with sub-questions composed of claim, warrant, data, and rebuttal. Table 1 shows the tests for "reflection of light" and "thermal expansion and contraction" as examples.

After these two test papers were compiled, they were reviewed by two scholars in the field of science education who studied argumentation to determine if these papers were based on the theoretical foundation of test paper design. Then, the papers were reviewed by two science teachers who had majored in physics, to decide if the contents of the papers were appropriate. Lastly, five 8th graders outside the two groups were invited to read the questions and explained them, to make sure the questions were written properly with words that the 8th graders could understand.

After the argumentative ability tests for "light" and "temperature and heat" were performed and marked, 20 test papers from each group were randomly selected and given to another judge, who also marked these papers based on the scoring rules. The results were analyzed using Pearson product-moment correlation. The reliabilities obtained were 0.91-0.93 and significant ($p < 0.05$). Thus, the marks given by the judges were consistent.

Table 1

The Argumentative Ability Test Questions for “Reflection of Light” and “Thermal Expansion and Contraction”

Main concept	Stem	Questions for students to answer
Reflection of light	There are two theories of light below: Theory A: Light travels from our eyes to the object we see. This is how we see that object; Theory B: Light comes from a light source and is reflected by the object we see to our eyes. This is how we see that object.	Do you support theory A or B? Why do you support that theory? Can you provide some evidence to support that theory? What is the reason you do not support theory A or B?
Thermal expansion and contraction	There is a metal ball that can just go through a metal ring perfectly. If we heat this ball and the ball expands, it can no longer go through the metal ring. What if we heat the metal ring instead of the metal ball? Can the ball go through the ring this time?	What is your prediction? The ball can go through the metal ring. The ball cannot go through the metal ring. What is your reason for this prediction? Why do not you predict the other result?

Data Collection and Analyses

The data collected by this study for the purposes of qualitative and quantitative analyses included the students' sectional exam score before the teaching was given, the scores of the argumentative ability tests for “light” and “temperature and heat,” and the videos of the teaching for the experiment group.

In the aspect of qualitative data analyses, the first thing was to mark the argumentative ability test papers. The scoring rules were based on Toulmin's (1958) argumentation pattern which is composed of claim, warrant, data, and rebuttal. It includes claim, claim-warrant, claim-warrant-data, and claim-warrant-data-rebuttal, with gradually increasing scores for these rules. In addition, in order to distinguish those who did not answer and those who supported the wrong claim, the score given to the former and later were zero and one point, respectively.

Based on the rules above, two points were given to those who supported the right claim, three points were given to those who supported the right claim with a right warrant, four points were given to those who supported the right claim with a right warrant and right data, and five points were given to those who supported the right claim with a right warrant, right data, and right rebuttal. These rules applied to the argumentative ability test questions for “reflection of light” in Table 1 and the marking results are summarized in Table 2. All the other questions (imaging with a plane mirror, imaging with a convex, thermal equilibrium, heat and temperature changes, and thermal expansion and contraction) were designed with only three elements, namely, claim, warrant, and rebuttal, so the scoring rules applied were reduced according to the rules above, with zero to four points. The students' total scores for the three questions of the argumentative ability test for “light” were their performances for this test, and their total scores for the three questions of the argumentative ability test for “temperature and heat” were their performances for this test. Moreover, the percentages of students who did not answer the argumentative ability test questions were between 0% and 6% with the average being 2%.

In order to compare the experiment group with the control group in terms of argumentative ability performances for “light” and “temperature and heat,” the students' science sectional exam scores before the teaching was used as the covariate variable and their argumentation ability test scores for “light” and “temperature and heat” after the teaching as the dependent variables to perform ANCOVA for the purpose of removing the influence of their science learning achievements before the teaching on their argumentative ability performances. Then, this study set the significance levels for all statistical tests to 0.5. Moreover, in order to explore the effects of the treatment, this study adopted the effect size indicator η^2 proposed by Cohen

(1992) for analysis of variance (ANOVA). The values representing large, medium, and small effects were 0.14, 0.06, and 0.01, respectively.

In the aspect of qualitative data analyses, regarding the coding for the argumentative teaching for the experiment group, “T” represented the teacher, “S 28” represented the student No. 28, and “SG 1” represented students from Group 1. The underlined words represented the words used for argumentation during the argumentative discourse by the teacher and the students. Based on the quantitative data analysis results, related teaching scenarios were adopted for corresponding illustrations.

Table 2

The Scoring Rules for the Argumentative Ability Test Questions for “Reflection of Light”

Score	Rule	Answer example
0	The question was not answered.	Blank
1	The wrong claim was supported.	I support the claim that light travels from our eyes to the object we see. This is how we see that object (S 6 of the control group).
2	The right claim was supported without warrant or with an inappropriate warrant.	I support the claim that light comes from a light source and is reflected by the object we see to our eyes. This is how we see that object. The reason is that our eyes cannot emit light (S 19 of the experiment group).
3	The right claim was supported with an appropriate warrant.	I support the claim that light comes from a light source and is reflected by the object we see to our eyes. This is how we see that object. The reason is that light follows the rule of reflection in the same medium. It is reflected by the object and goes into our eyes to form an image on our retina. This is how we see that object (S 8 of the experiment group).
4	The right claim was supported with an appropriate warrant and proper data.	I support the claim that light comes from a light source and is reflected by the object we see to our eyes. This is how we see that object. The reason is that light follows the rule of reflection in the same medium. It is reflected by the object and goes into our eyes to form an image on our retina. This is how we see that object. The evidence is that if you place a ball in a dark room and look into the room, you cannot see the ball (S 9 of the experiment group).
5	The right claim was supported with an appropriate warrant and proper data, while the wrong claim was rebutted.	I support the claim that light comes from a light source and is reflected by the object we see to our eyes. This is how we see that object. The reason is that light follows the rule of reflection in the same medium. It is reflected by the object and goes into our eyes to form an image on our retina. This is how we see that object. The evidence is that if you place a ball in a dark room and look into the room, you cannot see the ball. The other claim is not correct, because if our eyes can emit light, we should be able to see the object in the dark room without turning on the light. But what happens is that we cannot see the object until we turn on the light (S 2 of the experiment group).

Findings and Discussions

The Relationship Between the Students’ Argumentative Ability Performances and the Teaching for the Unit “Light”

The first unit being was “light.” A week later, the argumentative ability test for this unit performed. ANCOVA was applied with the students’ first science sectional exam scores before the teaching as the covariate variable and the dependent variable being argumentative ability performances. According to Table 3, for the covariate, $F(1, 67) = 52.64$, $p = 0.00$, and $p < 0.05$. The result was significant, meaning that besides different teaching methods, the first science sectional exam scores could also influence the argumentative ability test result for the unit “light.” Moreover, for the test of regression homogeneity, $F(1, 66) = 0.87$, $p = 0.35$, and $p > 0.05$. The result was not significant, meaning that the relationship between the covariate and the dependent variable would not be influenced by the levels of the independent variables. The homogeneity hypothesis was not rejected. The ANCOVA could be carried on. According to the ANCOVA result in Table 3,

$F(1, 67) = 2.92$ and $p > 0.05$. The result was not significant, meaning that with the influence of the first sectional exam removed the difference in argumentative ability performance for the unit “light” between the experiment group and the control group was not significant. Table 4 shows that the adjusted average score for the experiment group was 7.35, while that of the control group was 6.56.

Table 3

Summary of the Results of the ANCOVA for the Argumentative Ability Test for “Light” With the Two Groups

Source of variation	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P</i>	η^2
Covariate	180.76	1	180.76	52.64	0.00*	0.44
Group	10.04	1	10.03	2.92	0.09*	0.04
Error	230.08	67	3.43			
Total	420.87	69				

Note. * $p < 0.05$.

Table 4

The Means (M), Standard Deviations (SD), and Adjusted Means (AdjM) of the Two Groups’ Scores of the First Sectional Exam and the Argumentative Ability Test for “Light”

Test/Exam	Experiment group ($N = 35$)			Control group ($N = 35$)		
	<i>M</i>	<i>SD</i>	<i>AdjM</i>	<i>M</i>	<i>SD</i>	<i>AdjM</i>
First science sectional exam	72.54	13.42		64.11	15.73	
Argumentative ability test for “light”	7.77	2.60	7.35	6.14	2.06	6.56

Although the argumentative ability performances for “light” between the experiment group and the control group was not significantly different, from the perspective of teaching method, it could be found that the learning environment for the experiment group was different from that of a general classroom. Regarding the teaching of argumentative discourse for the experiment group, Mr. Chen started with Toulmin’s (1958) argumentation pattern with the purpose of teaching the students to use argumentative expressions. Then, the important concepts from the unit “light” were used as examples to help the students to understand how these argumentative expressions are linked together to convince others.

For example, Mr. Chen asked the students, “If someone questions the fact that ‘light travels in a straight line,’ how they would convince that person that the fact is true?” This question seemed to make the students ponder. Mr. Chen waited for a while, but no one responded. Then, Mr. Chen further asked, “What other ways can we use to convince others to support the claim we support?” After that, Mr. Chen wrote on the blackboard, “My warrant is that when the light shines on an object, there would be a shadow on the other side of the object as the light cannot reach that area.” Then, he turned off the lights in the classroom, leaving only the light from the projector. He asked a student to come up and do some gestures in front of the projector. What happened was that a shadow appeared on the projection screen. The student became exhilarated and started to make different hand shadow puppets. This was when the students’ learning motivation was triggered. Someone put up his hand to ask a question, “Mr. Chen, did you ask that student to make hand shadow puppets as an evidence to convince us?” This kind of demonstration helped the students to find out how the argumentation elements, such as claim, warrant, data, rebuttal, etc. were linked together to form the structure of argumentation. Mr. Chen often asked the questions below to trigger his students’ argumentative discourse:

1. What warrant can you propose to support your claim?
2. Can you come up with the data to support your claim?
3. Can you associate with your warrant with some concept you have learned before as a support?
4. Do you have any further warrant to support your claim?

Mr. Chen used these questions to guide his students to perform argumentative discourse. When an embryonic form of argumentative discourse could be seen, he assigned the students into groups for group practices of argumentative discourse, to encourage them to include more argumentative expressions in their discourse. For example, Mr. Chen asked the students a question to make them think, “Why does the textbook say that camera lens is convex lens?” Then, he asked another question to make the students come up with a warrant to support this claim and think about “Why concave lens would not work?” “What warrant can you propose to support this claim?” Here, Mr. Chen introduced an opposite subject matter as the competition theory to facilitate the students’ argumentative discourse.

At first, the students did not say much. Thus, Mr. Chen offered another hint as he asked them, “Can you associate with your warrant with some concept you have learned before as a support?” He was trying to lead the students to think about the concepts from the “light” unit they had learned and see if any one of them could be used to support their claim. At this moment, the students became more active in the discourse. They started to come up with data from their experiences of photographing and experiment results.

T: Can you associate any of the concepts taught before?

S 30: We all have some experiences of taking pictures. According to the imaging of photo, the image of the object on the film is smaller than the actual object. This image should be a reduced image. This is my data.

S 6: I agree with XX Cheng (S 30). Last time, when the teacher performed the experiment of light-emitting diode (LED) light imaging, the distance between the object and the convex had to be at least two times the focus length of the convex to create a reduced and upside-down image on the other side of the convex.

At this moment, S 7 “objected” as he believed that S 6’s data were incorrect. He presented his own experiment result as his data. When the other students heard S 7 using the term “objected,” they all laughed. Mr. Chen took this opportunity to tell his students that the term to be used was “rebutted” instead of “objected” when not agreeing with the other person’s claim, data, or warrant. Mr. Chen also asked the student to come up with his warrant and data, as this is how good thinking is done.

T: Well done. You are all correct. You all helped to clarify this paragraph from the textbook. It does take a convex to create a reduced image of the object on the film. However, XX Wang (S 7), please remember do not use the term “objected” again in this kind of situation. You should say something like “I do not support this claim. My rebuttal is ... or my warrant is ...” This way is better.

At first in the class, the students were not used to Mr. Chen’s argumentative teaching method. They preferred Mr. Chen to tell them the answer after he asked a question. They were not comfortable with speaking. Therefore, sometimes, the content of their argumentative discourse was not very complete. Sometimes, they did not know how to come up with warrant. In rebuttal, they would even use critical words. However, after continuous demonstrations, suggestions, and clarification by Mr. Chen, the quality of the students’ argumentative discourse became higher. They started to understand that this kind of learning method could help them to clarify some concepts. Also, they could hear different voices from different people based on different warrant. Moreover, those who were brave enough to present their own claims had a chance to show off. And those who had always been quiet in classes were incited to participate in the discussions with their peers. This

learning environment which was helpful for argumentative discourse in the classroom of the experiment group was not seen in the classroom of the control group.

The Relationship Between the Students' Argumentative Ability Performances and the Teaching for the Unit "Temperature and Heat"

"Temperature and heat" is the second unit taught. The argumentative ability test for "temperature and heat" was conducted a week after the teaching. Then, this study applied ANCOVA with the students' first science sectional exam scores before the teaching as the covariate variable and their argumentation ability performances for the units "temperature and heat" as the dependent variable. According to Table 5, for the covariate, $F(1, 67) = 47.75$, $p = 0.00$, and $p < 0.05$. The result was significant, meaning that besides different teaching methods, the first science sectional exam scores would also influence the argumentation ability test scores for the units "temperature and heat." Moreover, for the test of regression homogeneity, $F(1, 66) = 0.66$, $p = 0.42$, and $p > 0.05$. The result was no significant, meaning that the relationship between the covariate and the dependent variable would not be influenced by the levels of the independent variables. The homogeneity hypothesis was not rejected. The ANCOVA could be carried on. According to the ANCOVA result in Table 5, $F(1, 67) = 16.51$ and $p < 0.05$. This means that with the influence of the first sectional exam removed the difference in argumentative ability performance for the unit "temperature and heat" between the experiment group and the control group was significant. Table 6 shows that the adjusted average score for the experiment group was 7.44, higher than that of the control group which was 6.56, meaning that the experiment group did better in the argumentative ability performance for "temperature and heat" than the control group. The experiment effect η^2 was 0.20, which was rather large.

Table 5

Summary of the Results of the ANCOVA for the Argumentative Ability Test for "Temperature and Heat" With the Two Groups

Source of variation	SS	df	MS	F	P	η^2
Covariate	118.62	1	118.62	47.75	0.00*	0.42
Group	41.01	1	41.01	16.51	0.00*	0.20
Error	166.44	67	2.48			
Total	326.07	69				

Note. * $p < 0.05$.

Table 6

The M, SD, and AdjM of the Two Groups' Scores of the First Sectional Exam and the Argumentative Ability Test for "Temperature and Heat"

Test/Exam	Experiment group (N = 35)			Control group (N = 35)		
	M	SD	AdjM	M	SD	AdjM
First science sectional exam	72.54	13.42		64.11	15.73	
Argumentative ability test for "temperature and heat"	7.74	1.93	7.44	5.54	1.84	5.85

When the teaching for the unit "temperature and heat" began, Mr. Chen once again helped the students review the expressions of argumentation and the relevant relation among these expressions. He also went further to teach the students how to apply these expressions and the corresponding effects through determining the "reliability" of a claim. Mr. Chen wrote a statement on the blackboard, which was that "feeding energy to

an object does not necessarily increase the temperature of that object.” He asked the students if it was possible to determine the reliability of this statement. That was a difficult question. The students were quiet. No one answered. Mr. Chen asked another question as a hint in hopes of inducing their thoughts.

T: Think about it. How can I say this to make you understand better and increase the reliability (of the statement)?

Still, no one responded. Thus, Mr. Chen wrote the four statements below on the blackboard and underlined the argumentative expressions:

1. I guess feeding energy to an object does not necessarily increase the temperature of that object.
2. I am sure feeding energy to an object does not necessarily increase the temperature of that object.
3. I have already investigated whether feeding energy to an object can increase the temperature of that object.
4. Based on the conclusion of my experiment, feeding energy to an object does not necessarily increase the temperature of that object. The warrant is that, according to the data of the experiment of ice melting into water, in a certain period of time during the heating process, the temperature of the object did not go up, while the only thing that happened was the ice keeping on melting into water.

Mr. Chen used the argumentative expressions, such as “investigated,” “warrant,” “according to,” and “data” as clues for the reliability of the statement that “feeding energy to an object does not necessarily increase the temperature of that object.” These expressions helped the students to determine the reliability of the statement that “feeding energy to an object does not necessarily increase the temperature of that object.” For example, “guess” and “sure” led to different reliabilities. Also, this example allowed the students to ponder if they could add argumentative expressions, such as “investigated,” “warrant,” “according to,” and “data” to increase the reliability of their claim.

The students became more interested in and familiar with the argumentative expressions above. Mr. Chen found an opportunity to guide the students’ argumentative discourse through a scenario. Mr. Chen presented a slide with the following description:

Here is a fact from our daily life, “In a bakery, if a customer buys an ice cream cake, the store clerk would put the cake in a Styrofoam box, so that the ice cream cake would not melt too quickly on the customer’s way home.”

Based on this experience, Ann said,

Because the specific heat of the Styrofoam box is high, the temperature of the box does not change easily. This is why the box can keep the cake cool. With this property of high specific heat, the Styrofoam box can also be used to keep hot steamed stuffed bun warm.

Do you support this statement? The warrant is _____. Therefore, our conclusion is _____.

Mr. Chen used a student’s alternative conception (Ann’s statement) as the material to induce the students’ argumentative discourse. The students were asked to carry on group discussions and each group should write down whether the group supported the statement and the corresponding “warrant” and “conclusion” on the blackboard. Mr. Chen reminded the students to apply as many argumentative expressions as possible. After five minutes of enthusiastic discussions, the groups’ arguments were written on the blackboard. The arguments of all the six groups are summarized below:

Group 1: We do not support this statement. Our warrant is that the density of the Styrofoam box is high. It is not easy to conduct heat. And our conclusion is that the reason why the Styrofoam box can be used for temperature preservation is the low conduction caused by the high density.

Group 2: We do support this statement. Because of the high specific heat, the temperature of the Styrofoam box does not go up or down easily. Therefore, it can be used for temperature preservation.

Group 3: We do not support this statement. Our warrant is that the Styrofoam box is a solid body, and inside the box, there is air. Our conclusion is that because the conduction of the Styrofoam box is low and the air convection inside is not good, the purpose of temperature preservation can be achieved.

Group 4: We do support this statement. Our warrant is that temperature preservation is associated with specific heat. Matters of high specific heat do not absorb heat nor release heat. Our conclusion is that Ann is right!

Group 5: We do not support this statement. (No warrant was provided).

Group 6: We do not support this statement. Our warrant is that temperature preservation has nothing to do with specific heat. Our conclusion is that the conduction of the Styrofoam box is not high, there is no air convection inside the box, and the box is while, so the box can be used for temperature preservation.

As shown by the arguments of the six groups, a lot of students were able to structure their argument using argumentative expressions. Because the arguments of the six groups were not consistent, there were differences, forming competitions between the arguments. Mr. Chen took this opportunity and led the students to the argumentative discourse activities of questioning, defending, and rebutting. Mr. Chen asked the groups to defend or rebut each of the arguments on the blackboard. He specifically reminded the students to avoid personal attack and to base their defense or rebuttal on “warrant” and “data.” The students from SG 1 rebutted the statement about the color of the box by Group 6. However, their rebuttal digressed. Mr. Chen timely reminded them to focus on the issue of the temperature preservation property of the Styrofoam box and the students’ defenses and rebuttals were focused again. Then, the students of Group 4 rebutted the argument by Group 1 that the high density of the Styrofoam box leads to its low heat conduction, and thus, the effect of temperature preservation. Group 4 believed that the theory behind temperature preservation should be air convection instead of conduction. As a result, Group 2 and Group 6 also joined to rebut the argument by Group 1 and Group 1 began to defend their argument.

SG 4: I would like to rebut the argument proposed by Group 1. It should be the air convection instead of the conduction of the Styrofoam box determining the effect of temperature preservation.

SG 2: I would like to rebut the argument proposed by Group 1. My warrant is that density has nothing to do with air convection.

SG 1: The argument we proposed is that due to the high density of the Styrofoam box, the heat can hardly go out of the box.

After Group 1 defended their “density” argument, Mr. Chen used metal as an example for the density of metal is high yet the heat conduction is still high to challenge the students, in hopes of encouraging them to think about different arguments. As a result, Group 6 suggested that the density of Styrofoam is lower than that of water as the data to rebut the argument by Group 1 that the effect of temperature preservation is based on the high density of Styrofoam.

T: Let me ask you all a question. The density of metal is high. However, the heat conduction of metal is also high. My warrant is that our pans are made of metal.

SG 6: If you throw Styrofoam into water, it would float. According to the definition of density, the density of Styrofoam should be lower than that of water. How is it possible that the density of Styrofoam is high? We believe that the warrant of Group 1 is wrong.

Then, Group 3 also rebutted the arguments proposed by Group 2 and Group 4. They believed that the effect of temperature preservation of the Styrofoam box has nothing to do with the specific heat. However, they did not clearly express their statements.

SG 3: We think that both Group 2 and Group 4 are wrong. In the aspect of energy, whether heat is absorbed or released by an object is not associated with the specific heat of that object.

Mr. Chen noticed that the time was almost up. However, the students still could not well rebut Ann's argument that "Because the specific heat of the Styrofoam box is high, the temperature of the box does not change easily, which is why the box can keep the cake cool" and proposed a reasonable argument in the argumentative discourse. Thus, Mr. Chen, on the one hand, praised the students' performances. And on the other hand, suggested the students to think about "the ways of energy transmission." Then, Mr. Chen concluded this class by clarifying and put forward the argument, addressing that the effect of temperature preservation is related to the low conduction of the Styrofoam box and the specific heat is not directly involved.

From the teaching plot analyses of the units—"light" and "temperature and heat," it can be found that with Mr. Chen's teaching of argumentation, the form of the students' discourse could gradually become more consistent with that of argumentative discourse, with more and more criticism and rebuttal for different arguments. As suggested by Osborne, Erduran, and Simon (2004), Erduran, Simon, and Osborne (2004), and Kuhn (2005), argumentation was considered good with alternative theories and rebuttal arguments. The discourse in Mr. Chen's classroom qualified as good argumentative discourse. Moreover, with the quantitative analysis results, it can be inferred that the students' argumentative ability improved in this learning environment. However, it would take a longer period of time to actually increase students' argumentative ability through argumentative teaching. This point was proven by the different result of the ANCOVA with the argumentative test scores for "light" and "temperature and heat."

Although the learning environment constructed by this study for the purpose of facilitating argumentative discourse worked with the effects mentioned above, the teaching plot analysis result also showed some of the students' problems regarding the argumentative teaching:

1. The students did have the intention to support or rebut other arguments, though they could not come up with proper warrant or data;
2. The students' warrant to support or rebut a certain argument contained some misconceptions;
3. The students missed the point of the competition theory and the direction of the rebuttal was away from the subject at issue;
4. The students could not come up with a convincing argument based on science.

To resolve these problems, Mr. Chen had tried demonstration, offering hints, asking questions, and guidance to urge the students to create more appropriate argumentative discourse. He had also clarified, commented on, and put forward arguments to help the students further understand the concepts involved in the arguments. These were all the responding measures taken for the argumentative discourse learning environment designed by this study.

Conclusions and Implications

Developing the argumentative ability is an important issue, when it comes to improving students' science literacy. This study designed an argumentative discourse learning environment based on the literature review. After the verification based on the design of experiments, it was found that a longer period of learning (a total of 30 sessions for two units in this study) could efficiently improve the 8th grade students' science argumentative ability. This finding can be used as a reference for teachers to design their argumentative teaching.

In an argumentative discourse learning environment, for the students who were new to argumentation, the most fundamental and essential part of learning argumentation was learning argumentative expressions. When the argumentative teaching was given, the groups' different arguments were used as competition theories to urge the students to defend or rebut each other's argument based on what they had learned. When being faced with a competition theory, the students could see the difference between their arguments, and thus, they were more willing to participate in the argumentative discourse. During this process, the students compared their own argument with others' through the argumentative discourse and then came up with warrant and data to support or rebut. This was an opportunity for them to improve their argumentative ability. Furthermore, with the teacher's clarification, comments, and help to put forward the arguments, the students were more likely to go beyond the limit on their learning and turn the learning opportunity into learning results.

Although in the process of argumentative discourse, the students still had problems, such as: (a) not being able to propose proper warrant or data; (b) having misconceptions in their warrant; (c) deviation from the subject at issue during the argumentative discourse; and (d) not being convincing enough with science theories. Yet, the hints and the questions helped the students to identify the differences between the competition theories and their argument, so that the focus of the discourse could be kept on the subject at issue. And the demonstrations and guidance helped them to come up with warrant and data, resulting in a huge amount of argumentative discourse. Then the teacher had a chance to see the students' problems with argumentation. Through the teacher's clarification, comments, and putting forward effective arguments, the students learned the knowledge of argumentation, had their conceptions clarified, and had deeper insight into argumentation.

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