The Influence of Argumentation Strategy on Student's Web-based Argumentation in Different Scientific Concepts

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***Abstract*—Argumentation is an important aspect of the scientific education. The purpose of the present studies was to explore the influences of two variables termed "the argumentation strategy" and "the kind of science concept" on student's argumentation in the web-based learning environment. There were two types of argumentation strategies (individual or collaborative) and two kinds of science concepts (descriptive or theoretical) identified for our experimental investigations. The quasi-experimental method was applied in which 138 7th grade students were invited and then assigned into either individual group (N=68) or collaborative group (N=70) randomly. They then participated into a web-based learning pro-gram we developed for six science topics, including three descriptive and three theoretical topics. Several scaffoldings were embedded into the program explicitly and systematically, such as multi-media, a discussion block, and scripts in order to promote students' learning engagement. The students' arguments pro-posed during the web-based learning, including claims, warrants, backings and rebuttals were clarified, coded, and then analyzed. The results showed the argumentation strategy has a significant effect on students' argumentation only in the theoretical topics. The post-hoc analysis showed the students in the collaborative group outperformed their peers significantly in the individual group. In theoretical science topic, the students needed more scaffoldings to acquire an in-depth understanding which supports them to construct multiple types of arguments. Moreover, the students in both groups made significant improvements no matter for the descriptive or the theoretical topics, implying the web-based learning pro-gram was effective for argumentation learning.**

***Keywords*—Argumentation, Collaborative learning, Kind of science concept, Web-based learning.**

I. INTRODUCTION

Argumentation is an important aspect of the scientific enterprise and also an essential aspect in science education (Henderson, McNeill, González-Howard, Close, & Evans, 2018; Jonassen & Kim, 2010; Kilinc, Demiral, & Kartal, 2017). In recent science and technology educational research, the problems of how teachers to integrate argumentation in the science teaching, and how to promote students to argue scientifically have been widely concerned especially for the application of web-based learning environment (Henderson et al., 2018; Kilinc et al., 2017). Kuhn (2005) proposed a triangle model to explain how argumentation helps knowledge construction. There are three elements emphasized in the Kuhn's model: one' perspective, the other's perspective, and external information. The first two perspectives indicates a relationship between individuals, it implied a characteristic of collaborative argumentation which is a main strategy/approach to create scientific theory or principle. Relatively, the opposing strategy as to the collaborative argumentation approach is individual argumentation, a traditional approach for early scientists to construct arguments (Jiménex-Aleixandre & Erduran, 2008). The third element, the external information, not only indicating the knowledge background of an arguer but also the subject, e.g., concept, or knowledge, being discussed. According to Lawsons' theory, they indicated science concepts can basically be divided into either descriptive or theoretical (Lawson, Alkhoury, Benford, Clark, & Falconer, 2000). In the research of physics and chemistry education, the two kinds of science concepts were termed as macro- or micro-level concept respectively (Dori & Hameiri, 2003). However, researchers in science education rarely take both the two factors: argumentation strategy and kind of science concept, into concern when explaining the leaning of argumentation. Osborne et al. (2016) reported that the learning of scientific argumentation could be considered as knowledge dependent activity (p. 840). Thus, the two factors could be important factors in the learning of science argumentation. The present study developed a web-based argumentation learning program to investigate students' argumentation. We compared the collaborative strategy with the individual one under the two kinds of science conceptual learning environments: descriptive and theoretical. The research questions are as follows: (1) Whether the factor of collaborative or individual argumentation strategy effects on students' learning of science argumentation, if so, how? (2) Whether there is difference between descriptive and theoretical conceptual learning regarding the argumentation performances? (3) Can the argumentation learning program improve the ability of science argumentation? if so, how?

II. LITERATURE REVIEW

A. Collaborative and individual argumentation strategies

Basically, the strategy of how we argue can be classified into two types (Kilinc et al., 2017; Jiménex-Aleixandre & Erduran, 2008). The first type is monological strategy, which is also called individual argumentation strategy which can be regarded as strategy with 'involving implicit dialogues and is deductive, focus on a single inference' (van Eemeren & Grootendorst, 1984, p. 12). Individual argumentation strategy is usually descripted as 'a chain of reasoning' (Reed & Long, 1998, p. 2), and with the intuitive 'case building' of presenting arguments in support of the thesis (Reed & Long, 1998, p. 3)'. On the other hand, the second type is dialogical argumentation strategy, which is also called collaborative argumentation strategy. The collaborative argumentation

978-1-7281-3388-1/19/$31.00 ©2019 IEEE
DOI 10.1109/ISET.2019.00031

strategy emphasizes on intellectual openness, social relationships, creative thoughts and possibilities for criticism (Evagorou & Osborne, 2013; McNeill, González Howard, Katsh-Singer, & Loper, 2016; Moon, Stanford, Cole, & Towns, 2017). Moon et al., (2017) indicated that students' collaborations can facilitate them to generate sound arguments, especially in the contexts or tasks needed higher-order thinking skills for problem solving.

However, Kilinc et al. (2017) indicated that "most science teachers prefer monologic discourse during teaching science, though learning science as argument necessitates dialogic discourse environments. Teachers usually benefit from question-answer-evaluation sessions that do not permit argumentative virtues or student-student interaction …" (p. 766). Apart from science teachers, previous studies had indicated that it may not easy for high school students to engage in argumentation no matter in individual or collaborative strategy (Bell, 2004; Moon et al., 2017). It had been reported that students basically have little ability to: (a) explore relevant data, and science information accurately (Bell, 2004), (b) apply the science information for constructing a generalizable claim (Moon et al., 2017), (c) incorporate evidence to support or defend their claim (Sandoval & Millwood, 2005), and (d) rebut counterargument by using evidence from multiple resources (Osborne et al., 2016). To solve the problems, educators in technology and computer-based learning developed multiple kinds of online learning programs and reported this could be an effective way to enhance the students' science abilities such as understanding of science concept, argumentation (Moon et al., 2017), and peers' collaboration (Kilinc et al., 2017; Weinberger, Stegmann & Fischer, 2010). Lindwall et al. (2015) applied a number of argumentative scripts into the Facebook apps to and investigated the students' argumentation and knowledge co-construction. They found the scripts especially for peers' collaborations could provide significant support for the solidification of the students' prior knowledge which benefits their science argumentation learning. The present study took the suggestions of previous studies on computer-based learning and developed a web-based argumentation learning program to investigate students' science argumentation.

B. *Kind of Science Concepts*

Previous studies reported that science concepts could be categorized into a number of types based on the degree of being apprehended by the learners (Lawson et al., 2000; Piaget & Inhelder, 1969). Lawson, Abraham, and Renner (1989) identified three kinds of science concepts: directly sensed, descriptive, and theoretical concept. In general, the first type of science concept is the concept that can be immediately sensed, such as color, internal state concepts (hunger), and external state concepts (cold and hot). The second type of science concept, descriptive concept, refers to concept that cannot be immediately sensed. This type of concept is usually termed as macro-level concept in science education research. The third kind of concept, theoretical concept, is an advanced concept which can be sensed only through indirectly observation. It is also called micro-level concept, mass conservation and chemical reaction rate are examples of this type of concept. Piaget & Inhelder (1969) explained the degree of comprehending toward the different types of concept is basically different in his theory "intellectual development". That is, comprehending the theoretical concept could be the most difficult one among the three concepts mentioned above. Especially for elementary and high school students, it is not easy for them to acquire direct observations or experiences regarding the learning of theoretical concepts. Another problem in comprehending the theoretical concept would be the learning transfer from the descriptive to the theoretical concept, this cognitive process is a complex and nonlinear thinking process (De Vos & Verdonk, 1996; Dori & Hameiri, 2003). In the research of science education, whether different kinds of science concepts affect argumentation is still a question that remains to be resolved. Thus, we considered that the collaborative argumentation strategy may provide support for learning the theoretical concept. In our consideration, when developing web-based learning program for supporting argumentation it is necessary to take both the argumentation strategy and the kind of science concept into concern.

III. Mehods

A. *Participants and procedures*

The quasi-experimental design was applied in which four classes, totally 138 7th grade students were invited and participated into the present study. Before the research semester, the students' science scores from the last semester were collected and analyzed in order to assign them into two groups homogeneously: individual group and collaborative group ($t = .197$, $sig > .05$). The individual group (N=67) received the monological argumentation learning environment, while collaborative group (N=70) received the dialogical argumentation learning environment. For the collaborative group, the size of each subgroup was about three to five members.

The present study developed an online learning program called the program of web-based argumentation learning (PWAL) to investigate students' argumentation in the two learning environment. Before participating into the program, all students had to attend a 45 minutes long introductory course in order to make sure that they all acquired basic knowledge regarding science argumentation, such as the basic elements for a sound argument and their relationships. The Toulmin's argumentation pattern and the four elements in the pattern were introduced and explained to all the students (Toulmin, 1958). These elements were: 1) claim, 2) warrant, 3) backing, and 4) rebuttal. After that, all students participated into the PWAL during the school day in the curriculum called "group activity".

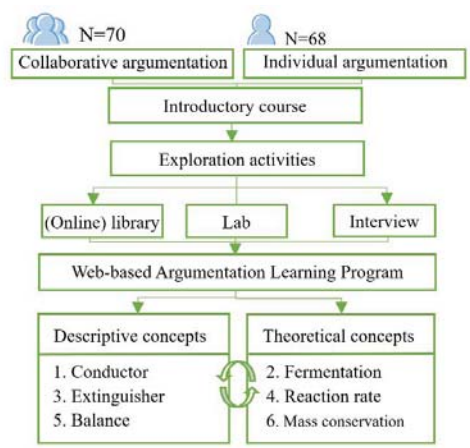

Fig. 1. The experiment procedure of the present study

The curriculum was a two hours per week curriculum, which emphasized the development of students' science abilities, such as science argumentation, inquiry, and collaboration. These abilities were important for the national curriculum reform of our country during the research semester.

There were six science topics selected from the current high school science curriculum standards as learning materials of our research experiment. These topics were: (1) electrical conductor, (2) ethanol fermentation, (3) fire extinguisher (4) chemical reaction rate, (5) balance & weight, and (6) the law of conservation of mass. The first, third, and fifth topics emphasizes the learning of descriptive science concepts, while the other three topics emphasizes learning of theoretical concepts. After the introduction course, all the students were encouraged to explore the relevant information about given topic for two hours. They were allowed to go to in school (online) library, lab (if necessary) for collecting data and relevant information. Some of them even interview their parents, teachers, and friends about the topic in order to collect data from multiple resources. Then, they were invited into a school computer classroom and participated the PWAL learning for 45 minutes. The students could still log into the PWAL after school till a new topic was began. It usually took one week to complete one topic of learning in the PWAL. Figure 1 shows the research design and experiment procedure.

B. *Program of web-based argumentation learning (PWAL)*

The PWAL was created based on a number of educational principles: interest, explicit script, interactive, multi-media embedded, and synchronous (Demirbag & Gunel, 2014). After logging into the PWAL, the students were provided a short instruction to explain how to complete one topic of the learning tasks, including how to watch and play the embedded video, how to explore and review the related information, and how to propose arguments, and so on. There was a 3-4 minutes introductory video embedded in the PWAL as the first activity for introducing the given topic. The introductory video was created by our research team showing the students the relevant science experiment, and phenomenon. After introductory video, the next learning page is argumentation interface in which an open-ended question was provided at the top of the page.

In order to support the students to argue based on science evidence, the PWAL provided two to three explicit scripts for constructing the four types of arguments respectively: claim, warrant, backing, and rebuttal. For instance, the explicit script "according to the definition/ theory that … I agree with that…" was provided for constructing a warrant. Moreover, the script "I do not agree with the point /idea at/on … because it does not meet with the theory/point of …" was used to construct a rebuttal. The PWAL had two versions, one was created for the individual group students while the other one was for collaborative group students. For the individual version, students can propose argument without any communication with their peer during the online argumentation activity. On the other hand, the students in the collaborative version could construct arguments through peers' communication, so that they can see all arguments proposed by themselves and their peers in the discussion block. Except for the discussion block, most of the learning materials and interfaces for the two versions were the same.

C. *Coding criterion of argumentation*

The main data of the present study was the students' scores of the four arguments claim, warrant, backing, and rebuttal, proposed in the PWAL. A criterion for coding the arguments was created based on a number of previous studies on argumentation learning (Hogan & Maglienti, 2001; Osborne, Erduran, & Simon, 2004; Osbone et al., 2016). All the student statements were recorded in a file and read line by line by the two researchers (a science teacher and a Ph.D. candidate). They categorized all the students' statements into the four categories: claim, warrant, backing, and rebuttal. Any off-task portions of the conversation were removed. Then, each argument was evaluated according to the completeness of its logic, content, and relevant explanation (Hogan & Maglienti, 2001). A high quality (level 2) argument was identified as argument with rational discourse, relevant to the given topic, and support by scientific facts, data, theory, or principles. On the other hand, a low quality (level 1) argument was identified as argument without any supportive facts, evident, or clear connection to the given topic. Level 2 and 1 argument was scored as 2 and 1 point respectively. The cross-coder reliability was completed by the two researchers above and the value was 0.85.

TABLE I. CODING CRITERION

Category	Definitions	Coding criterion
Claim	A deductive conclusion constructed based on data or materials.	Level 1: a conclusion without any supported data or fact. Level 2: a conclusion with clear supported data or fact.
Warrant	A question from a science theory or principle in order to support the claim/conclusion.	Level 1: a simple reason, without any supported theory, or the reason is not related to the claim or not correct. Level 2: a reason with clear supported theory or principle and is related to the claim.
Backing	A detailed description based on life experience or experimental data.	Level 1: a reason from life experience but not related to the claim, incorrect, or not clear. Level 2: a reason with clear supported evidence or experience and is related to the claim.
Rebuttal	A statement to question or criticize an unreasonable conclusion.	Level 1: unexplained or unclear critique, or counterclaim. Level 2: a counterclaim with a clear explanation.

Through the coding criterion, we transferred the qualitative data into quantitative data. Then, the repeated measures ANOVA was applied to explore the two group students' argumentation learning in both the descriptive and theoretical science topics.

IV. RESULTS

The results of repeated measures ANOVA was conducted with the sum of the argumentation scores across the descriptive and theoretical topics as dependent variables. The results (Table 2) showed no significant difference of the students' argumentation between descriptive and theoretical science topics ($F_{(1, 138)}$=4.52, p>.05).

TABLE II. REPEATED-MEASURES ANOVA ANALYSIS FOR THE DESCRIPTIVE AND THEORETICAL TOPIC

	N	M	SD	MS	F(p)	η^2
Descriptive	138	18.12	6.00	134.96	4.52	.032
Theoretical	138	19.52	6.67			

Note: * p < .05, ** p < .01, *** p < .001

The repeated measures ANOVA was conducted with the argumentation strategy (the individual and collaborative group) as between-subject variable, while the sum of three descriptive and theoretical topics as within-subject variables. The results (Table 3) revealed that the argumentation strategy ($F_{(1, 138)}$=48.19, p<.001, η^2=.262) has a significant effect on argumentation in the theoretical topics. The post hoc results showed that the students in the collaborative group outperform their peers significantly in the individual group. However, there was no significant difference between the two groups in descriptive topics.

TABLE III. REPEATED-MEASURES ANOVA ANALYSIS FOR THE INDIVIDUAL AND COLLABORATIVE GROUP ACROSS THE DESCRIPTIVE AND THEORETICAL TOPICS.

Sources	N	M(SD)	MS	F(p)	η^2	Post-hoc
Descriptive topic			127.73	3.614	.026	
Individual	68	17.15(5.36)				
Collaborative	70	19.07(6.46)				
Theoretical topic			1593.96	48.19***	.262	C>I
Individual	68	16.07(3.47)				
Collaborative	70	22.87(7.31)				

Note: * p < .05, ** p < .01, *** p < .001

Figure 2 shows the mean scores and results of independent-sample t-tests for comparing the individual group with collaborative group in three descriptive topics: electrical conductor (t(1,138)=.94, sig>.05), fire extinguisher (t(1,138)=1.84, sig>.05), balance & weight (t(1,138)=.93, sig>.05). That is, the students in collaborative group had better scores in the three descriptive topics than their peers in the individual group, however, there was no significant differences between them.

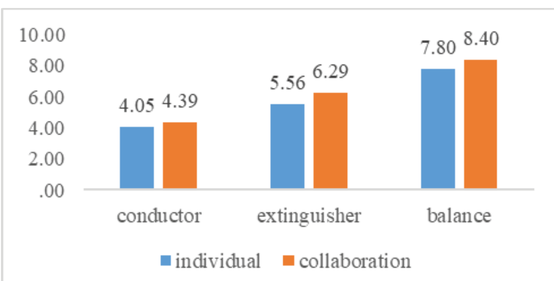

Fig. 2. the argumentation of the collaborative and individual group in three descriptive topics

Figure 3 shows the mean scores and results of an independent-sample t-test for the individual and collaborative group in three theoretical topics: fermentation (t(1,138) = 7.20, sig < .001), reaction rate (t (1,138)= 6.13, sig<.001), and mass conservation (t(1,138) = 2.53, sig < .01). The results revealed the argumentation strategy had significant influence on students' argumentation. The students in the collaborative group outperformed their peers in the individual group across the three theoretical topics.

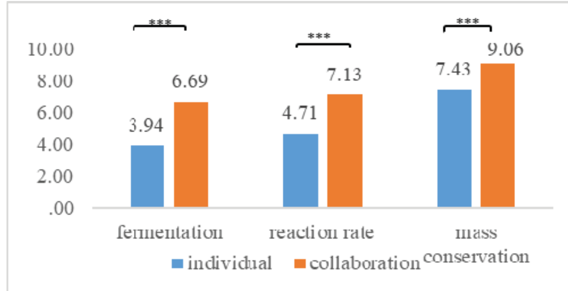

Fig. 3. the argumentation of the collaborative and individual group in three theoretical topics

The repeated-measures ANOVA was conducted for the three descriptive and theoretical topics respectively to explore the students' learning progressions regardless of the argumentation strategy in the PWAL. The results showed that they had a significant progress from the earlier descriptive topic to the later one (F(2,138)=75.42, p<.001, η^2=.39). There was a significant difference between the topic 1 and 3 (MD (mean difference) =1.71, p<.001), between the topic 3 and 5 (MD=2.18, p<.001). The similar results regarding the learning progressions were also revealed in the three theoretical topics (F(2,138)=31.60, p<.001, η^2=.26). There was a significant difference between the topic 2 and 4 (MD=0.60, p<.05), and between topic 4 and 6 (MD=2.32, p<.001).

TABLE IV. REPEATED-MEASURES ANOVA ANALYSIS FOR THE THREE DESCRIPTIVE AND THEORETICAL TOPICS.

Topic	M(SD)	MS	F(p)	η^2	Post-hoc
Descriptive		615.30	75.42***	.359	3>1*** 5>3***
1.Conductor	4.22(2.10)				
3.Extinguisher	5.93(2.32)				
5.Balance	8.11(3.76)				
Theoretical		262.09	31.60***	.187	4>2* 6>4***
2.Fermentation	5.33(2062)				
4.Reaction rate	5.93(2.61)				
6.Mass conservation	8.25(3.85)				

Note: * p < .05, ** p < .01, *** p < .001

V. DISUCCION DISCUSSION AND CONCLUSION

A main finding of the present study was that the online collaborative argumentation strategy is more effective than the individual one especially in scenario of the theoretical topics. The theoretical concept is generally more difficult for the students to ac-quire accurate comprehension then the descriptive one (De Vos & Verdonk, 1996; Lawson et al., 2000). The students may feel a necessary to communicate their com-prehension with their peers to acquire in-depth understanding regarding the given topic before they can apply them in argumentation. Importantly, the scaffoldings embedded in the PWAL support such kind of knowledge communications, such as discussion block and scripts. This would be a reason to explain the collaborative group students had more chances to use multiple types of arguments in the PWAL. On the other hand, in the individual version, the students were not allowed to communicate with their peers, they can generate arguments through self-reflection and knowledge recall process which limited their usage of multiple types of arguments. They were still beginner in learning argumentation after all.

Through the comparison analysis between argumentation in descriptive and in theoretical topic, we suggested science teachers have to be aware of the feature of the learning content/topic when teaching argumentation. It also implied educators to consider the type of science concept in the development of web-based learning program. Another statistic finding was that there is no significant difference between the descriptive and theoretical topic in term of the students' argumentation score. That is, although the theoretical science concept may increase the difficulty for the students' scientific argumentation in both groups, the abundant discussions and knowledge evaluations in the collaborative group mitigate the insufficiency of arguments of the individual group. Importantly, the individual group students still could perform as well as their peers in the collaborative group in the three descriptive topics. These findings indicated that the collaborative scaffoldings may support the students' argumentation but its effectiveness may reach significant differently only in the theoretical type of science topic.

Moreover, the statistic results indicated all the students made a significant progress in both the descriptive and theoretical topics. It implied that argumentation learning via web-based program can facilitate the students' argumentation significantly. In our case, the scripts embedded in the PWAL were constructed based on explicit approach. Furthermore, we tried to improve the students' learning motivation by embedding synchronous discussion block, multi-media, and encouraging them to explore related information from multiple resources such as using the internet, conduct a lab experiment and so on. These scaffoldings and multiple learning activities may explain why the students' learning progress. Based on the interest in computer-based learning, the present study further suggested that the development of online scaffoldings especially for the theoretical science concept should emphasize on the peers' collaborations, such as to provide opportunities for knowledge co-constructions and co-evaluations. As to the individual group students, they applied a different strategy to argue, a more traditional strategy used by most of early scientists, and we believe such strategy still has potential to be as good as their peers with collaborative strategy. The question is that how we can do it through the computer-based instruction. This is a direction for our future research.

ACKNOWLEDGMENT

This work was supported mainly by the China social science university humanity, China, under [number 18YJC880050].

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