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An Argumentation-Based Study with Concept Mapping Approach in Identifying Students' Scientific Performance Skills

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ABSTRACT

The application for burning incenses case study both indoors and outdoors is a controversial issues of value-laden and moral dilemma in Taiwan. This research aimed at using the argumentation-based case study as burning incenses with concept mapping approach in identifying students' learning performances towards scientific process skills. It was followed by an argumentation-based approach of pre-tests, post-tests and interviews designed for 139 qualified participants. All data collected from two experimental group students' argumentation-based learning performances and feedback was further analyzed by means of open-ended achievement tests, descriptive statistical analysis of learning attitude and the narration of students' interviews. Analytical results indicated that the argumentation-based texts were successfully designed for students' learning guidance by instructor. An evaluation tools with content validity and good reliability (Cronbach's $\alpha > .9$) were developed to assess students' argumentation-based learning performances. The achievement posttest finding revealed that two experimental group students enhanced their science argumentation skills of higher level than pretests. The further t-test of achievement posttest didn't indicate any significant differences ($p > .05$) for two experimental group students. Students' positive learning feedbacks also provided the predominant advantage for activating responsive reasons, promoting their critical thinking, enhancing self-confidence of science process skills and supporting teachers in argumentation teaching.

Keywords: argumentation-based, burning incenses, concept mapping, learning performance

INTRODUCTION

Argumentation discourses will be a meaningful students' participation for direct practices in constructing their new conceptions and science subjects. Many distinguished science educators, such as Eichler, Norris and Sampson put much emphasis on students' augmentation-based curriculum to activate reasoning processes and solve subsequently their new problems appropriately in science learning (Eichler & Peeples, 2016; Norris & Philips, 2012; Sadler, Romine, & Topçu, 2016; Sampson & Blanchard, 2012). More contributions testified in students' argumentation-based practices could provide authentic conceptual recognitions to decipher different theories on debate and modify their evidence development in contrast with traditional learning activities (Osborne, 2010). This study also proposes several critical cases learning with reasoning skills assessments to encourage students get both authentic involvements and achievement in scientific performance (Fogleman, McNeill, & Krajcik, 2011; Venville & Dawson, 2010).

Up to now, significant approaches of case studies have proved to be an influential tool to examine students' argumentation-based reasoning skills through students' mutual interactions and practices (Jimenez-Aleixandre & Erduran, 2008). To be active participants, students are required to activate their scientific understanding and literacies (Aydeniz, Pabuççu, Çetin, & Kaya, 2012; Çetin, 2014; Chin, Yang, & Tuan, 2016) in search for more scientific

accumulations of content knowledge (Venville & Dawson, 2010). After a series of argumentation-based reasoning skills, it becomes students' target learning to develop individual competencies in accordance with whole life attitude of sustainability learning (Tsai, 2018). The pedagogical framework for argumentation-based reasoning skills will be grounded on instructors' heightening applications which construct more teaching confidence in lifting up students' learning performances reciprocally (McNeilla, Katsh-Singera, González-Howarda, & Loper, 2016). All the above approaches of argumentation-based science learning are designed to help students follow a step-by-step comprehensive understanding as case participation in science classroom (McNeilla et al., 2016).

Instead of just memorizations, meaningful engagement and practice should be the major priority in constructing students' learning performances with the application of concept mapping (CM). The use of CM combined with argumentation-based science learning guides most students to explore their critical thinking abilities for organization, categorization, analyses, estimation and reasoning (Novak, 2010). Scholars have agreed that CM not only could enhance students' cognition structures but also serve as a smart instrument between instructors' argumentation-based teaching and students' case learning (Schultz, 2008; Selvaratnam & Canagaratna, 2008; Peng, Su, Chou, & Tsai, 2009). To follow scholars' point of view, CM is regarded as the best effective learning instrument to cultivate and present for their problem-solving abilities in scientific learning of case studies (Su, 2017; Nicoll, Francisco, & Nakhleh, 2001).

Based on the above assumption, this research takes burning incenses from daily life as the prime exemplar in constructing students' argumentation-based case study. It deals with students' learning performance by exploring their interest and motivation. Accordingly, the incorporation of a new design of argumentation-based learning strategy will help students make their participation upon their decision-making through scientific reasoning processes. Students will present their scientific conceptual understanding by warrant, backing, rebuttal and claim in the case study of burning incenses both indoors and outdoors.

Three Aims of Study Perspectives

The research aimed at students' argumentation-based cases study with concept mapping in constructing their scientific learning skills. Based on the above assumption, three fundamental research questions were proposed as the following:

1. What can be testified for the benefits of students' argumentation-based case study with CM?
2. What advantages will students get after a series of argumentation-based learning strategy and attitude in different cases of burning incenses?
3. What attributes can be grouped as students' feedback after surveys of their interviews?

METHOD

Samples

The research samples of participants consisted of 139 undergraduate students from a Taiwan technological college. All 139 students are required to pass an entrance examination to register for author's science course with their ages distributed from 20 to 22 in college. Through two stages of chemistry qualification tests, at least two third students had passed the second trial of accumulated chemistry knowledge. Up to the final qualification test, 64 students with higher-order cognitive skills had received full prior knowledge in average grade scores 75 who could respond more advanced chemistry performances at the case research standard requirement. To avoid the Hawthorne effect (Su, 2018), 64 participants were randomly assigned into two groups evenly, namely Group E1 (grouped as positive claim), and Group E2 (grouped as negative claim). All participants in this research gave full informed consent in the process of science experiment (Taber, 2014).

Research Design

For the CM research design, two experimental group students (E1 and E2) were included in burning incenses with the argumentation-based case study. Functionally towards different purposes,

E1 group was instructed to take the negative claim without burning incenses, and E2 Group was instructed to take the positive claim with promoting burning incenses in Table 1. The subsequent E1 and E2 group students' instructions follow the author's science education program. It took two hours per week for students to follow their burning incenses instructions within the 12 hours argumentation-based learning strategy. Students' demonstrations of reasoning skills would be inferred to their manipulation of burning incense both indoors and outdoors in Taiwan. It also enacted students to develop an important guidance which demonstrated more detailed follow-up discussions in Table 1. To be a coherent guidance (Cross, Taasoobshirazi, Hendricks, & Hickey, 2008; Driver, Newton, & Osborne, 2000; Ural & Gençoğlan, 2020), this study approached Toulmin's argumentation pattern as 6 basic constituents (1958, see Figure 1) in the following of argumentation-based case:

Data, to be important sources in students' argumentation-based case study for burning incenses both indoors

Table 1. Experimental research design of the argumentation-based learning strategy

Group	Pretest	Experimental treatment	Posttest	Learning attitude
E1 (32ps)	Open-ended achievement test	Argumentation-based science concept mapping teaching approach-- without burning incenses	Open-ended achievement test	Attitude scale test
E2 (32ps)	Open-ended achievement test	Argumentation-based science concept mapping teaching approach-- promoting burning incenses	Open-ended achievement test	Attitude scale test

and outdoors

Warrant, for argumentation reasons with science laws, principles, rules or theories.

Backing, to justify argumentation warrants from group students' discussion.

Claim, to select from two different group students' argumentation facts as their conclusions.

Qualifier, to represent scientific truth and specify how the argumentation was to be used to limit.

Rebuttal, as the necessary argumentation presentation when the claim was not reasonable or true.

Discovering Data Tools

Multiple sources of data were adopted in the research to give more interactive narrations of both argumentation and science knowledge representation. The data were collected through administering open-ended achievement tests, science learning attitude scale and interviews of learning feedback.

Developing of Achievement Tests. The open-ended achievement tests were prepared by author' argumentation-based case study as burning incenses with CM approach for assessing students' learning achievements in the research. There were three test items in the open-ended argumentation-based achievement tests. The draft scale of the achievement tests was reviewed and revised by 7 senior science specialists to examine its validity. The argumentation-based achievement test items were scored by the standard of Table 1 (Sadler & Donnelly, 2006) as the prior knowledge of argumentation-based pretest and dependent variable of posttest. The Cronbach α reliability coefficient of the open-ended achievement pilot test was .96. The test results showed high reliability for the open-ended argumentation achievement tests (Salta & Tzougraki, 2004). The achievement pretest and

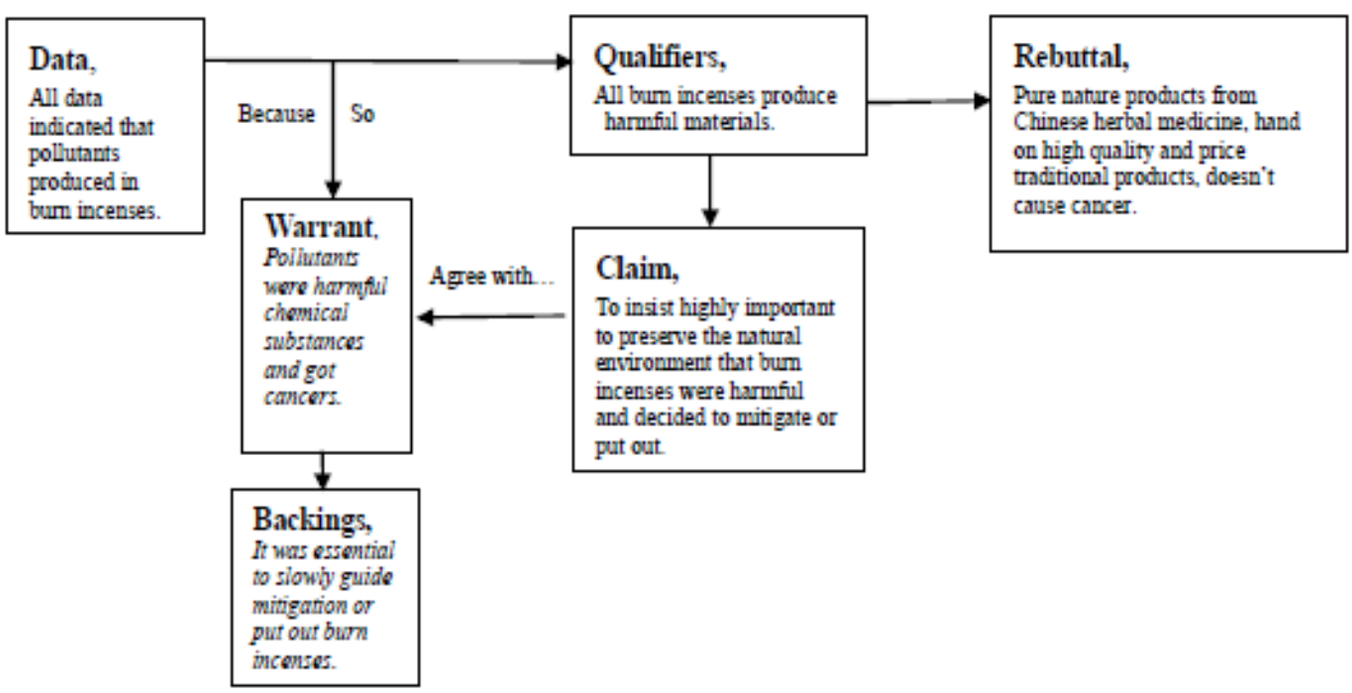

Figure 1. The basic constituents of argumentation-based case study for burning incenses with CM

posttest related to both indoors and outdoors which should inflict mitigation or put out the burning incenses, were scored 0 point for giving blank, no answer or vindicate; 1 point for only giving accept or agree or vindicate without argumentation; 2 point for giving some simple argumentations to vindicate; 3 point for providing some smart argumentations, and 4 point for not only providing some smart argumentations but also having opposite views on the question (Sadler & Donnelly, 2006). All results in three achievement tests could get the highest score 12.

Designing of Learning Attitude Scale. The perception questionnaire of science learning attitude was developed as the first draft from Su (2016) and Sadler & Donnelly (2006). The draft scale was reviewed and revised by 7 senior science specialists to examine its content validity through students' argumentation-based understanding. The attitude scale consisted of 30 test items each based on a 5-point Likert type scale. Furthermore, 75 students' pre-tests were taken into consideration for factor analysis as the constructive validity. The main component analyses of the questionnaire showed six Eigenvalues above 1.0 with an accumulative explanation variation of 71.85%. Six subscales were classified by specialists as dominating dependent variables in the perceptions questionnaire of learning attitude, such as toward argumentation-based learning texts (Q1), toward argumentation-based learning surrounding (Q2), toward argumentation-based instructors (Q3), toward students' argumentation-based interests of participation (Q4), toward argumentation-based self-evaluation (Q5), and toward argumentation-based statistical results (Q6). The total scale score of the Cronbach's α .96 indicated the high internal consistency of the perceptions questionnaire of science learning attitude (Salta & Tzougraki, 2004).

Interview of Semi-structure. In addition to the above structural questionnaire for students' argumentation-based learning achievements, this study also offered semi-structural interview analysis to acquire their authentic expression opinions. Nine students were randomly selected from two group students after their post-tests. The interview contents of argumentation-based comprised the design of science process context, promotion of science reasoning skills, perception of strategic learning attitude and students' intuitive responding, and all contents of learning feedback as a qualitative analysis.

Data Collection, Treatment and Analysis

The quantitative scoring and coding techniques of qualitative interviews were two important procedures for data collection, treatment and analysis in this study. Quantitative data included open-ended achievement tests and questionnaire of learning attitude in the argumentation-based learning strategy. The quantitative analysis involved t-test, descriptive statistics, testing scores, and Cronbach's α. All statistical information was acquired before or after the classes was carried on the file of SPSS 22.0 Windows software. The follow-up interviews came from students' learning feedback of argumentation-based case study as qualitative data.

RESULTS AND DISCUSSION

As burning incenses with the argumentation-based case study, this study consisted of two stages in the dynamic design processes. The first stage provided students' preliminary analysis of open-ended achievement test, while the second stage gave their learning attitude and interviews. Moreover, this study analyzed students' different learning performances in argumentation-based case study, such as pre-tests, post-tests, learning attitude and feedback with fundamental research results.

Analyses of Learning Achievement

In research question 1, what can be testified for the benefits of students' argumentation-based case with CM? From development of quantitative discussions, there were three open-ended test items to assess all students' pretest and posttest response percentages before or after the argumentation-based learning strategy, as indicated below. Students' response results of pretest and posttest indicated as blankness, no answers or vindications with 0 score up to the average percentages which got reductions from 40.9% to 12.0%. Students could accept, agree or vindicate without argumentation and could be grouping as 1 score in the average percentages be reduced from 24.6% to 20.3%. To get their promotions from 31.6% to 48.4%, students could vindicate some simple argumentations and got 2 score. Students got 3 score and raised percentages from 2.9% to 16.7% for vindicating some simple argumentations. Finally, when they got 4 score and uplifted from percentages 0% to 2.6%, students not only vindicate some simple argumentations with fine reasons but also proposed their rebuttal.

To set up Toulmin's (1958) argumentation-based case study as framework, this research was based on the constructive theory of Ausubel (1968) and concept mapping (Su, 2017), as well as the functional CM guidance design for burning incenses. Tsai (2018) pointed that the argumentation-based case text included balance reports of positive (group E2) and negative warrants (as group E1). The reports helped students to construct scientific process skills of controversial dilemmas of argumentation-based case study with burning incenses in this study. Barab

et al. (2007) and Sadler, Klosterman, and Topcu (2011) proposed that the argumentation-based case text could promote students' understanding of science conception through guidance instructions of burning incenses both indoors and outdoors.

The t-test of achievement tests didn't indicate any significant differences ($p > .05$) for two experimental group students in this research. The tests representations promoted students' science learning achievement for argumentation-based reasoning skills up to the higher level. The result provided direct evidences to support students' argumentation-based learning, especially the effective guidance strategy could help them to construct fundamental scientific knowledge (Chin, Yang & Tuan, 2016). In their development of learning activity, group E1 students could provide own superiority with scientific argumentation knowledge to refute opponents' claims as in the cases of group E2 students (Asterhan & Schwarz, 2007). Therefore, more researchers (Knight-Bardsley & Mcneill, 2016; Nielsen, 2012; Schalk, van der Schee, & Boersma, 2013; Weng, Lin, & She, 2017) pointed that teachers' guided instructions of the argumentation-based learning strategy would be an essential challenge to improve students' science knowledge understanding and construct their science process skills.

Analyses of Learning Attitude

Students' learning attitude responded to more advantages of burning incenses both indoors and outdoors for the research question 2 after a series of argumentation-based learning strategy and attitude in the study. This research highlighted the argumentation-based strategic application of learning attitude for students' perception questionnaire. The descriptive statistical analyses in students' argumentation-based learning attitude of the six subscales were assessed with the total mean score 3.65 (> 3.50) and the standard deviation .68 for all their learning attitudes (Su, 2008, 2018). The completed questionnaire was analyzed to yield total Cronbach's α value .96 which indicated the statistic result of authentic high satisfactory degree (Salta & Tzougraki, 2004).

The differential effects of the argumentation-based learning strategy were explored in students' attitude scale. Group E1 students took the negative claim without burning incenses, decided to mitigate or put out burning incenses those pollutants would produce harmful chemical substances and got cancers for both indoors and outdoors. However, group E2 students took the positive claim with promoting burning incenses and thought that pure nature products from traditional herbal medicine hand on high quality and price products didn't cause any cancer or harm. This study demonstrated more extended benefits to the argumentation-based strategic application than traditional textbooks learning (Adesope & Nesbit, 2013; Lin & Atkinson, 2011). The advantages of strategic application would play a positive role for students' science learning attitude, enhance problem-solving abilities, facilitate critical thinking skill and promote them for science authentic understanding. As researchers Chin, Yang and Tuan (2016) proposed their interpretations that argumentation could provide some related issues to illustrate essential characteristic of fundamental literacy as wise argumentation-based case leading to facilitate students' science understanding. Therefore, the results indicated that the argumentation-based learning strategy would give an important effect on two experimental group students' positive learning attitude towards science process skills.

Analyses of Students' Learning Feedback

What attributes can be grouped as students' feedback after surveys of their interviews? All participants' interview could clearly understand the benefits of using argumentation-based case study for burning incenses with CM approach on students' science learning process. For the subsequent interviews of the argumentation-based learning strategy, 9 students (be coded as S1~S9) were randomly selected from the counterpart students of two experimental group after they finished both open-ended post-tests and learning attitude questionnaire. The interview results of students were shown as the following:

> *The S1 response (Group E1) -- The incenses were burned to release formaldehyde, benzene and volatile organic compounds. When the particulates (PM2.5) were breathed deeply by nasal passage, it would cross to bronchus to directly go pulmonary alveolus. The PM2.5 will disturb gas exchange and cause inflammation in lung.*

> *The S2 response (Group E1) -- The teaching strategy will be an important thinking transfer for religious belief to change their habits. It was essential to slowly guide mitigation or put out the burning incenses for both indoors and outdoors by governmental dissemination in Taiwan.*

> *The S3 response (Group E2) -- It is impossible to change traditional religious custom of burning incenses in Taiwan.*

> *The S4 response (Group E2) -- Although my scientific knowledge is weaker than others, the integrated teaching will make my logic thinking clearly and construct new concept easily.*

> *The S5 response (Group E2) -- The teaching strategic application will help me to solve scientific questions easily from burning incenses.*

> *The S6 response (Group E1) --The integrated teaching*

made me to understand many harmful chemical substances from air pollutants, such as benzene, 1, 3-butadiene, toluene and vinyl benzene.

The S7 response (Group E2) --To be able to inspire my learning motivation, the argumentation-based learning strategy provided authentic conceptual guidance and comprehensive understanding in science program.

The S8 response (Group E2) -- I could clearly understand science concept and improve my reasoning skills by argumentation-based case.

The S9 response (Group E1) -- The strategic applications would enhance my chemistry knowledge about air pollutants and critical thinking skills based on argumentation-based case practice.

Students' learning feedback of the argumentation-based case study showed that it was more interesting than traditional learning of textbook lecture in science. As in the orientation of Osborne's research (2010), this study proposed that the teaching approach could provide meaningful argumentation-based practice to increase scientific knowledge and promote students' reasoning skills based on evidence. The teaching approach could also support instructors in argumentation-based case study (Cavagnetto, 2010) and increase their confidence in science teaching program (McNeill et al., 2016). Thus, the argumentation-based learning strategy would be able to construct students' science conceptual knowledge more effectively than the traditional or didactic teaching approach in science (Ural & Gençoğlan, 2020).

CONCLUSION AND IMPLICATIONS

This study conducted instructional experiments of the argumentation-based case study as burning incenses with CM functional learning activity on students' identified practices. The total design indicated that the argumentation-based strategy could enhance students' reasoning skills of controversial dilemmas and construct their positive science learning attitudes. However, up to now the argumentation-based case study was not often used by instructors in scientific or the other application curriculum. But when students came across controversial or dilemma events they were supposed that scientific instructors were hard to make a decision with authentic consensus conception in science approaches. In this case study, students' argumentation-based learning strategy could guidance them to construct meaningful argumentation knowledge, to confront more possibilities about environmental controversial issues, and to increase their reasoning skills in science.

More and more meaningful argumentation-based learning strategy would fulfill students' critical performances with different warrants for adopting the feasible scaffolding to guide their orientations of decision-making skills. With respect to students' learning performances, the argumentation-based strategy fully indicated that students could use predominant advantage to show expressive practice and enhance their higher order critical thinking abilities. When students cultivated fine and positive learning attitude in science curriculum by the argumentation-based case study as burning incenses with CM, they could enhance their basic literacy and cognitive understanding in the designing scientific processes. Furthermore, the argumentation-based attitude could activate students' learning habit and promote their heightening value and vision in science critical thinking. In short, students' feedback revealed that the teaching strategy is a meaningful approach of science knowledge construction through argumentation-based case study. Students' positive learning feedback would also promote teachers' self-confidence in the argumentation-based instructions.

More future advantages will wait for students' direct participations in this argumentation-based case study to deepen their content-based explanation and cultivate their learning confidence in scientific demonstration. Thus, the further presentations of students' problem-solving skills will be observed in the present study to analyze and conduct through more strategic engagement and assessments for the argumentation-based case study.

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