Understanding and practice of argumentation: A pilot study with Mainland Chinese pre-service teachers in secondary science classrooms

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Abstract

Argumentation is recognized as a significant aspect of science education for the development of students' scientific literacy, and the science teacher is the key factor in organizing argumentative discourse in the science classroom. Composing argumentation in the classroom requires teachers to not only acquire the basic understandings and skills of argumentation themselves, but also to develop strategies for effective implementation of argumentation in the classroom. The purpose of this paper is to examine pre-service teachers' understanding and practice of argumentation in science teaching. Three pre-service science teachers participated in this study. Their understanding and practice of argumentation in the classroom were examined at the beginning of their teaching practice in terms of three aspects: a) understanding of argumentation, b) ability to compose argumentation; and c) practice with regard to developing argumentation in the classroom. Class observations and interviews were conducted to collect data. Two models were used to analyze the quality of the argumentation and the question types used in the science lessons given by these pre-service teachers. It was found that they had limited understanding of argumentation, and their abilities to compose scientific argumentation were also weak. Corresponding to their limited understanding and skills of argumentation, the questions they raised in the classroom were also not likely to stimulate argumentation. Thus, little argumentation took place in their classrooms.

Introduction

Science education has long been criticized for placing too much emphasis on scientific knowledge transmission while failing to develop students' scientific literacy (Driver, Newton, & Osborne, 2000). To reverse this negative trend, great efforts have been made by science educators, and a number of strategies and theories have been developed in the past several years. Among these new approaches, argumentation has caught the eye of science educators since it began to be discussed in science education in the latter part of last century. A number of studies on argumentation have been published in international journals in the past few years (e.g. Clark & Sampson, 2007; Driver et al., 2000; Erduran, Simon, &

Osborne, 2004; Kuhn, 1993; Lawson, 2002; Lawson, 2003; Maloney & Simon, 2006; McNeill & Pimentel, 2010; Osborne, Erduran, & Simon, 2004; Zohar, 2008). The central role of argumentation in science teaching and learning has also been discussed in past studies (Brick & Bell, 2008; Driver et al., 2000; Kuhn, 1993). However, argumentation rarely automatically takes place in science classrooms today (McNeill & Pimentel, 2010). One premise of successfully implementing argumentation in the classroom is the science teachers' professional development (Lawson, 2002). Zohar (2008) argued that to implement argumentation in science lessons, science teachers need to experience a fundamental shift in their pedagogical understanding and practice. In other words, science teachers' limited understanding may be an obstacle to implementing argumentation. An exploration of science teachers' understandings and skills is both significant and necessary to develop countermeasures to improve argumentation in science education today. Although the area of argumentation has attracted the attention of an increasing number of science educators, according to a search using the key word argument* on the ERIC online data base, few studies have been done in the Greater China area and even fewer have been conducted in Mainland China. While a search using the key word 论证 (argumentation) on the CEPS[1] for journal articles in Chinese from 2002 to 2012 yielded 725 articles, a quick look at the titles of these articles, focusing especially on those related to science education, showed that there were about 20 papers from Taiwan and only one from Mainland China. In conclusion, few studies of argumentation have been conducted in Mainland China to date.

This study explores pre-service science teachers' understandings, skills and their instructional practice of argumentation in science classrooms in Mainland China. Three pre-service science teachers volunteered to be involved in this study. Their understandings and skills of argumentation were examined. At the same time, the questions they raised in their lessons during their field experience were also examined. This study can provide us with an initial understanding of pre-service science teachers' status with regard to argumentation, and provide evidence for future studies in this area in Mainland China.

Literature review

Understanding argumentation in science education

[1] CEPS: http://www.airitilibrary.com/index.aspx, a database for journal articles in Chinese.

Argumentation is not a new word to the public and it is also widely used in our daily life. It has long been discussed in philosophy. In the Oxford Dictionary of Philosophy (Blackburn, 2005), argument is defined as follows, "considerations designed to support a conclusion. An argument is either the process of doing this ... or the product...the pattern of inference and the conclusion reached...Logic is the study of valid and invalid forms of argument"[2] . Van Eemeren and Grootendorst (2004) defined argumentation as "a verbal, social and rational activity at convincing a reasonable critic of the acceptability of a standpoint... (see p.1)." In this definition, standpoint is addressed as a significant part of argumentation. From the description above, we can identify some specific characteristics of argumentation. Firstly, it is a kind of verbal expression which is used when the individual standpoint is not accepted by others. Secondly, in order to persuade others, logic is necessary in argumentation. In general, the logic is built based on an acceptable connection between the claim and data. Thirdly, the process of constructing logic in argumentation implies an internal thinking process, and the external expression makes the thinking visible (Kuhn, 1993).

Differing from every-day argumentation, scientific argumentation not only possesses the characteristics mentioned above, but also places more stress on rational thinking. In other words, the connection between claims and data should be built based on rational thinking. It is widely accepted that argumentation consists of scientists' rational thinking processes, and scientific argumentative expression makes this thinking visible (Kuhn, 1993). The concern of argumentation in science education is influenced by its role in science.

In the past, argumentation was viewed as the language of science (Driver et al., 2000) and as a core epistemic practice in science (Brick & Bell, 2008). It is widely accepted that argumentation plays a central role in scientific practice (Brick & Bell, 2008; Driver et al., 2000; Kuhn, 1993). Any scientific theories are developed based on full arguments. In order to make conclusions acceptable, scientists should also construct argumentation very carefully, starting from the research design. Despite its importance, argumentation has not received due attention in science education in the past. However, with the movement of research studies on argumentation, its role in science education has been discussed (e.g., Clark & Sampson, 2007; Driver & Newton, 2000; Erduran, Simon, & Osborne, 2004; Lawson, 2003; Maloney &

[2] Retrieved on 2nd May 2011 from the web of online Oxford Dictionary of Philosophy: http://www.oxfordreference.com/views/ENTRY.html?entry=t98.e239&srn=1&ssid=330499839#FIRSTHIT

Simon, 2006; Osborne, Erduran, & Simon, 2004). It is widely accepted that argumentation plays a central role in scientists' work (Brick & Bell, 2008; Driver et al., 2000; Kuhn, 1993) and thus it should also be an essential goal of science education (McNeill & Pimentel, 2010).

Difference between argumentative and traditional science classrooms

Argumentation is a kind of verbal expression. To implement argumentation in science education means to change the discussion pattern in traditional science classrooms. As is well known, in traditional science classrooms the discussion is always led by the teacher. The teacher initiates questions, students respond or reply to the questions, and then the teacher evaluates the students' answers (McNeill & Pimentel, 2010; Mehan 1979). This has been named the IRE pattern. To search for the right answer is the main objective in this kind of science classroom. In order to help students get the correct answer, most questions in the IRE pattern are closed questions and students just need to reply using low-level recall, short utterance responses (McNeill & Pimentel, 2010). In such classrooms, the science teacher is recognized as the sole authority who determines the direction of the discussion. Students are not central to the lesson. Compared to this traditional IRE pattern, many differences can be found in argumentative classrooms.

First of all, to acquire scientific knowledge is not the single objective in argumentative classrooms. As argumentation has been recognized as a core scientific practice, by experiencing argumentation in science classrooms students not only deepen their scientific knowledge understanding but also develop understanding of the nature of science and develop the skills related to argumentation. Secondly, the question types given by teachers are different. In argumentative classrooms, more open-ended questions are raised with the aim of stimulating students' argumentation (McNeill & Pimentel, 2010). Open questions have been regarded as crucial to the occurrence of argumentation in science classrooms (Osborne et al., 2004). Thirdly, in argumentative classrooms, the discussion pattern is changed in that the discussion may be initiated by the students themselves, and they have more opportunities to voice their opinions. Different answers and conflicts are welcome in the classroom discussion (Simon, Erduran, & Osborn, 2006). In conclusion, in argumentative classrooms, students have more opportunities to compose argumentation and they play a more central role in science learning.

The science teacher has been regarded as crucial to the implementation of argumentation in the science classroom (Martin & Hand, 2009). Since there are so many differences between traditional IRE and argumentative classrooms, to implement argumentation in science learning, the science teacher should acquire sufficient understandings and skills.

Teachers' role in promoting argumentation in the science classroom

"Effective teaching requires prior understanding" (Lawson, 2002, p237). There are many factors which affect science teachers' instructional practice of argumentation. Science teachers' abilities of argumentation have been identified as one of these factors (Lawson, 2002). However, past studies have indicated that science teachers' performance of argumentation tends to be relatively limited. Lawson (2002) investigated 22 pre-service biology teachers' argumentation performance by analyzing students' laboratory reports, and found that when faced with unobservable evidence, pre-service teachers have relatively weak ability to compose hypothetico-predictive arguments. Since scientific argument is different from argument in daily life (Sampson & Gerbino, 2010), composing scientific argumentation is always a challenge to science teachers. Past studies have also indicated that science teachers even face difficulties providing evidence of the fundamental tenets of contemporary science (Durant, Evans, & Thomas, 1989; Erduran, Ardac, & Yakmaci-Guzel, 2006).

Science teachers' pedagogical understandings are also significant in implementing argumentation. Zohar (2008) indicates that to improve argumentation, science teachers need to make a fundamental shift in their pedagogical understandings. Science teachers' pedagogical understanding of science education objectives is one of the important factors influencing their teaching practice. However, "the ability to develop argument is a goal not usually set in science classrooms" (Jiménez-Aleixandre, Rodríguez, & Duschl, 2000, p781). In addition, to implement argumentation, the role of science teachers should also change from being the centre of the classroom to being the facilitator of students' learning. Science teachers' understanding should also develop in this respect.

Methodology

This is a pilot study on pre-service science teachers' preparation for argumentation. The focus of this study is to identify pre-service teachers' understandings and skills of composing argumentation. The instructional practice with regard to argumentation in science lessons without intervention at the beginning of their teaching practice was also examined in this study. Three research questions guide this study:

1. How do the pre-service teachers understand argumentation in science education?
2. What argumentation skills do they have?
3. How do pre-service science teachers organize discussions in the classroom?

This study was conducted in Zhejiang province in China. Three 4th year pre-service science teachers participated voluntarily without consideration of their background, gender, or academic performance. They had completed their theoretical curriculum learning, including courses such as *Scientific Curriculum and Teaching Theory, Science Instructional Design, the History of Science,* and *Scientific Research Methodology*. After finishing all the theoretical courses, they were preparing to undertake teaching practice in local secondary schools. The participants' profiles are listed in Table 1. Pseudonyms have been adopted to represent all the participants or others mentioned during the interviews.

Data collection

A qualitative research method was employed in this study. Firstly, a semi-structured group interview was used to probe the participants' understandings of argumentation. The interview questions consisted of two parts. The first set of questions was designed to explore their understanding of argumentation in terms of three dimensions: 1) their understanding of argumentation; 2) their understanding of the role of argumentation in scientific practice; and 3) their understanding of the role of argumentation in science education. The second set of questions was designed to capture their ability of composing argumentation. As scientific argumentation differs from argumentation in daily life, questions regarding these two different dimensions were included in the interview: some were related to the participants' personal daily life which would include every-day argumentation, while the others were related to the fundamental tenets of contemporary science, and invited them to compose scientific argumentation. In addition, three lessons for

Grade 8 students conducted by each pre-service teacher at the beginning of their teaching practice were video recorded to capture their teaching activities of organizing discussion in class. Both the interview and the science lessons were conducted in Chinese.

Table 1. The background and lesson topics of the three pre-service teachers

Name	Gender	Age	Student age	Lessons
Alice	Female	21	13-14	Dispersion of material in water
Tina	Female	20	13-14	Substances dissolve in water
Jane	Female	21	13-14	Substances dissolve in water

Data analysis

The interview was transcribed and translated into English by the researchers. The pre-service teachers' responses in the interview were divided into two categories: understanding of argumentation and performance of argumentation. Three sub categories, a) understanding of argumentation, b) understanding of the role of argumentation in scientific practice, and c) understanding of science education objectives in terms of argumentation, were developed to capture the pre-service teachers' understandings of argumentation. Their performance of argumentation was also analyzed according to two sub categories: a) skills of composing daily argumentation, and b) skills of composing scientific argumentation.

Osborne et al.'s model (2004) was used to evaluate these two types of argumentation. This model (Table 2) is popular in argumentation studies and has been employed in many past studies to evaluate the quality of argumentation (e.g., Chin & Osborne, 2010; Clark & Sampson, 2007; Dawson & Venville, 2010; von Aufschnaiter, Erduran, Osborne, & Simon, 2008). It was developed from Toulmin's (1958) argumentation pattern. According to this model, the participants' verbal expressions were coded into different levels representing different abilities of argumentation.

Table 2 Osborne et al.'s (2004) Analytical Framework

Level 1:	Level 1 argumentation consists of arguments that are a simple claim versus a counter-claim or a claim versus a claim.

Level 2:	Level 2 argumentation has arguments consisting of claims with data, warrants, or backings but does not contain any rebuttals.
Level 3:	Level 3 argumentation has arguments with a series of claims or counter-claims with data, warrants, or backings with the occasional weak rebuttal.
Level 4:	Level 4 argumentation shows arguments with a claim with a clearly identifiable rebuttal. Such an argument may have several claims and counter-claims.
Level 5:	Level 5 argumentation displays an extended argument with more than one rebuttal.

The science lessons conducted by the three pre-service teachers were transcribed verbatim. As the questions posed by science teachers are viewed as being significant in determining discussion in the classroom (McNeill & Pimentel, 2010; Osborne et al., 2004), all of the questions asked by the teachers in their lessons were tallied and divided into four types: open questions, closed questions, rhetorical questions, and managerial questions (Blosser, 1973; McNeill & Pimentel, 2010). The assumption was that more open questions would trigger more argumentation in the lessons. The coding scales are listed in the table below:

Table 3 Coding Scheme of the Questions Asked by the Teachers

Question type	Description	Example
Closed	Questions with limited answers	"Which one is the saturated solution?"
Open	Questions with many possible answers	"Why do fish live in the water?"
Management	Questions related to classroom management	"Who can answer the question?"
Rhetorical	Questions which don't need a reply but are employed for continuity	"Do you understand?" "Okay?"

Findings

Pre-service teachers' understanding of argumentation

According to the past literature, argumentation is not a new word to the public. In this study, the three pre-service teachers' understanding of argumentation was explored, and it was found that they had heard of argumentation but not in the area of science education. One of the teachers, Alice, tried to provide a general description of argumentation:

"I think argumentation is that, for example, my viewpoint is the earth is round, I should provide evidence, etc.; present my argument. I have learnt a little about this in debating."

She thinks that argumentation is a kind of expression which needs some support for the conclusion. On the whole, however, the three pre-service teachers' understandings of argumentation were limited. Two of them did not know how to describe argumentation at all.

Kuhn (1993) argued that the central role of argumentation in scientific practice has been widely accepted by the public. In this study, the three pre-service teachers' views on the role of argumentation in scientific practice were also probed by inviting them to describe the work of scientists. However, they did not mention argumentation in scientific practice. They all agreed that scientific inquiry is the core activity of scientists' work. However, they did not consider argumentation in scientific inquiry.

Argumentation was therefore a relatively unfamiliar word to these three pre-service teachers in the area of science education. Two of them, Alice and Tina, had never heard of the word "argumentation" in the area of science education, and Tina even thought that argumentation should only be discussed in philosophy lessons. The other participant, Jane, seemed to have heard of argumentation once in her past three years of theoretical learning, but she still showed some uncertainty about it. In addition, they all felt that it was strange to discuss argumentation in the area of science education. In conclusion, in this area, argumentation was a completely foreign concept to them, and their limited understandings came not from their past theoretical learning in science education but from other areas of their life.

These three pre-service teachers' views on science education objectives were also investigated in this study. The objectives related to argumentation, such as understandings of the nature of science, scientific rational thinking and the skills related to argumentation, were not mentioned in their responses. Rather, two other objectives were always mentioned: to realize the transmission of scientific knowledge and to cultivate students' interest in learning science. They considered that to cultivate students' learning interest is important; however, it is always abandoned when facing the objectives of scientific knowledge transmission. Jane

mentioned scientific critical thinking in her response, but she also admitted that it is an ideal perspective which is difficult to realize.

In conclusion, these three pre-service science teachers had very limited understandings of argumentation. They not only did not understand the role of argumentation in scientific practice, but they had also never heard of argumentation in the area of science education. The objectives related to argumentation were not taken into account in their teaching objectives. Argumentation was a completely new word to them in the area of science education. The responses of the three pre-service teachers to the interview questions are organized in Table 4.

Table 4 Pre-service Teachers' Responses to the Interview Questions

Understanding of argumentation	
Q1: Have you ever heard of argumentation? Have you ever heard of it in the area of science education before?	
Alice	I have never heard of argumentation in the area of science education before.
Tina	Argumentation? Has it been mentioned in the philosophy classes? I have never heard about it in science education.
Jane	Has it been mentioned in Miss Wang's lessons? I am not sure.
Q2: Could you describe your personal understandings of argumentation?	
Alice	I think argumentation is that, for example, my viewpoint is that the earth is round; I should provide evidence... present my argument. I have learnt a little about this in debating.
Tina	I do not know clearly what the meaning of argumentation is. I think argumentation is "explaining something with examples."
Jane	I forgot the meaning of argumentation and the content of argumentation was not addressed too much in the past instructional lessons in university.
Understanding the role of argumentation in scientific practice	
Q3: Could you describe scientists' work?	
Alice	Scientists' work is inquiry and the core activity of scientific thinking is inductive and deductive.
Tina	Inquiry should be the focus of scientists' work. The content of inquiry has been addressed so many times in my theoretical learning in university.
Jane	Inquiry can be viewed as the core practice of scientists' work. Inquiry represents a kind of thinking.
Understanding the role of argumentation in science education	
Q4: What are the objectives of science education?	

Alice	"First of all, to help students to understand scientific knowledge is the most important thing. If students cannot acquire enough scientific knowledge, they will fail in the examination and you must be a very unsuccessful teacher in China. Another thing I hope is that I can help my students to cultivate interest in science learning... For they always complain to me that they are too tired of learning."
Tina	The objective of science teaching is to cultivate students' interest. But science education today just emphasizes the scientific knowledge transmission from the science textbook to the students.
Jane	The objectives of science education should consist of two dimensions: transmission of scientific knowledge and cultivating students' interest in learning science. Furthermore, science education should develop students' ability to deal with problems by scientific critical thinking...Scientific thinking is critical and questioned. But it very difficult to realize in reality.

Pre-service teachers' ability to compose argumentation

These three pre-service teachers' ability to compose argumentation was examined in terms of two dimensions: daily argumentation and scientific argumentation.

Argumentation related to personal experiences

The three pre-service teachers' skills of argumentation were examined by inviting them to introduce one or two lessons and teachers that had impressed them the most. They showed different abilities of composing daily argumentation.

Alice

Alice introduced three teachers who had influenced her the most. In her statement, a sound argument emerged; her statements were clear and closely connected with warrants and backings. When her viewpoint was different from that of the others, rebuttal was adopted in her argumentation to defend her standpoint. For example:

> "I do not like the lessons given by Mr. Mark (claim) and I always sleep in his lessons (data). The lessons which impressed me most were The History of Science given by Prof. Walker (claim). Because in his classes I have a totally different feeling (data). There would be a topic in each lesson, and Prof. Walker would ask our views on this topic. Then he would explain the contents from different literature, and he would also provide his personal explanation (warrant). I feel so good in the lessons (backing). Although they give the same lessons, it's a totally different feeling compared to the lessons giving by

Mr. Mark (qualifier). Compared to Mr. Mark's four lessons, I learned more things in Prof. Walker's two lessons (rebuttal)."

According to Osborne et al.'s (2004) framework, the statement contains clear rebuttals and it can be classified as level 4 argumentation.

Tina

Tina also introduced the teacher who impressed her the most. Her favorite teacher was an exact contrast to Alice's. Tina's response was:

"In my personal opinion, I like Mr. Mark (claim). I thought his lessons were very good (claim). Although knowledge is addressed most in his lessons (warrant). And I have an interest in history so it may influence my opinion (backing)."

The statement shown above is the best example of argumentation from Tina's response. In this argumentation, the warrant and backing are included to support the claim. According to Osborne et al.'s (2004) model, Tina's statement can be classified as level 2 argumentation as it lacks any rebuttal. Tina's statement also shows emotive influence in the claim. Furthermore, in her statement the warrants cannot support the claim.

Jane

Jane's opinion is similar to Alice's. She also enjoys Prof. Walker's lessons, and dislikes the same lessons given by Mr. Mark.

Jane: "I think the teacher who influenced me the most is Prof. Walker (claim). Although I am not his student, I attend all of the lessons, The History of Science, given by him (qualifier). It's so great, a kind of respect feeling (data). He is a very guileless professor (warrant). You will never think he is a professor from his clothes (backing). I like the professors like him (warrant). In his lessons, he said he felt so sad that the science education in China is too backward (warrant). We all respect him (backing). Compared to him, the lesson given by Mr. Mark is too boring and he is too busy to deal with the different lessons (rebuttal)."

Jane's statements can be classified as level 4 argumentation as there is clearly rebuttal in her statement. However, we can still find an emotional factor in her statement.

In conclusion, when the questions are closely related to personal experience, these three pre-service teachers have the basic skills of composing argumentation, such as connecting claims and data, employing warrants and backing and even qualifiers and rebuttals in their argumentation. Although these statements are not at the highest level, their expression still provides us with evidence that argumentation exists in their daily life and they have a certain ability to compose argumentation. In addition, we can also find that in the daily argumentation given above, their opinions are not always neutral but are influenced by their personal emotions and less rational thinking. Words expressing emotion such as like, hate and dislike were frequently used in their argumentation.

Argumentation related to scientific knowledge

Three scientific propositions were adopted in the interview to investigate the participants' ability to compose scientific argumentation: 1) We live at the bottom of an ocean of air; 2) the shape of the earth is very close to spheroid; and 3) in our daily breathing exercises, we inhale oxygen, and exhale carbon dioxide and water (Simon, et al., 2006).

Alice is the only one who tried to make clear argumentation about these questions: "I want to argue the shape of the earth. Firstly, we think that the earth is round (claim) and this shape was recognized as perfect by people in the past (data). The ancients were inspired by the earth's shadow when there is an eclipse (warrant). According to the round shadow we can understand that the earth is round (backing). And then, if we take a boat in a southern direction, we can see the Polaris (qualifier). In this way, we can conclude that the shape of the earth is cylindrical (conclusion). When we take a boat from west to east, we may also find similar evidence (qualifier). So the shape of the earth should be spherical.....I think I cannot finish the argumentation in such a short time." In this argumentation, Alice tried to divide the problem into several parts and to argue each of them. Her argumentation can be classified into level 3.

Tina showed uncertainty about the scientific statements: "Exhale carbon dioxide... can we argue that in this way?...All these statements look very simple but I cannot make clear argumentation. Why do you ask us to argue these statements?" Actually, Tina did not want to evaluate the evidence to compose argumentation, but wanted to guess the intention of asking for responses to such questions in just a few

seconds. She also admits that when she was a student and was faced with the questions asked by the teacher, she always thought about what answer the teacher expected. She did the same here.

Jane did not compose any argumentation as she felt that the activity (i.e., composing argumentation for certain scientific statements) was very strange. She asked a question, "All these scientific statements have been proven by scientists and have been accepted by the public, so why do we need to try to argue them here?" She also thought that it was too difficult to compose scientific argumentation as she had never done it before.

In conclusion, when faced with scientific statements, these three pre-service science teachers showed an extremely low level of argumentation compared with their daily argumentation. The findings are consistent with those of Durant, Evans and Thomas' (1989) study. In this study, two pre-service teachers showed a positive and traditional view of scientific knowledge, meaning that they believe scientific knowledge to be objective and absolute truth. Two of them were not even ready to argue the scientific statements as they thought they had been argued by scientists already and had become known truths. Faced with scientific statements, these participants had limited ability and less confidence in composing argumentation. They even doubted the necessity of composing scientific argumentation. The details of the three pre-service teachers' argumentation levels are listed in Table 5.

TABLE 5 The Three Pre-service Teachers' Argumentation Levels

Name	Daily argumentation level	Scientific argumentation level
Alice	Level 4	Level 2
Tina	Level 2	Failed to give scientific argumentation
Jane	Level 4	Failed to give scientific argumentation

Use of open questions and closed questions in the science classroom

McNeill and Pimentel (2010) suggested that the questions used by science teachers directly determine students' argumentation in the science classroom; hence, all the questions asked by the pre-service teachers in the three lessons were analyzed to investigate the opportunities of argumentation provided. However, it was found that

more than 80% of the questions analyzed were closed questions, and most of these closed questions were followed with a short choral response from the students of 'yes' or 'no' without much time for thinking. No argumentation can be identified from these closed questions.

In contrast to the high proportion of closed questions, the percentage of open questions was very low. While 14.6% of Tina's questions were open, only 5.3% of Alice's and 8% of Jane's were. In other words, the number of open questions in the three pre-service teachers' classes was very low: 6 open questions in Alice's lesson, and 7 in Tina's and Jane's lessons. The percentages of the questions in the three lessons are presented in Figure 1. Open questions can support students' argumentation in the science classroom (McNeill & Pimentel, 2010), while few open questions brings little argumentation.

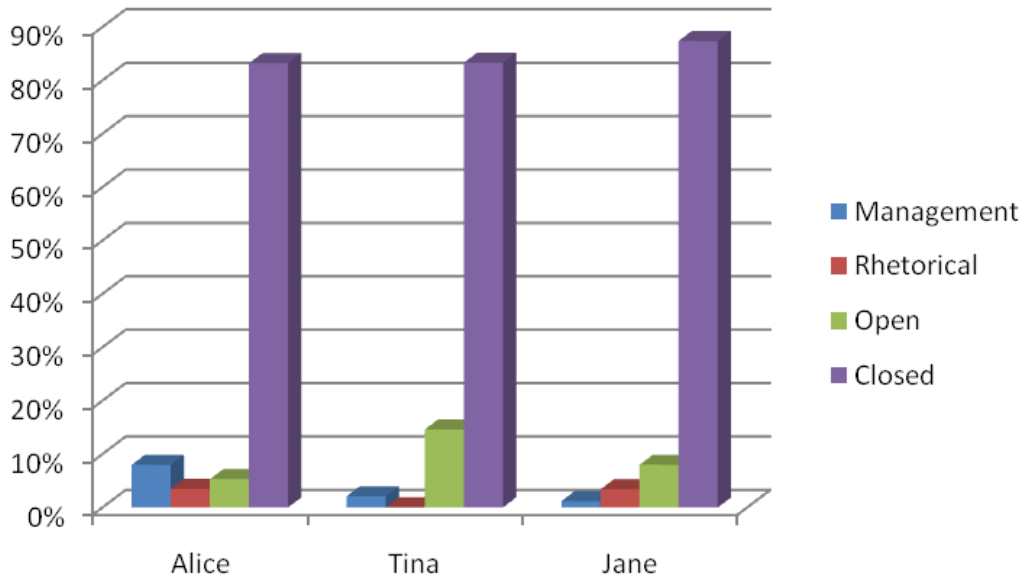

Figure1 Types of Teacher Questions in Three Lessons

Although there were a few open questions asked in the three lessons, not all of them were followed with students' argumentation. In Alice's lesson, just two open questions were followed with students' argumentation, while 4 questions in Tina's lessons and 6 questions in Jane's lessons were. Other open questions were inviting students to give examples or to describe the experiment they had observed. The details of the open questions asked in the three lessons are listed in Table 6.

Obviously, the students in these three lessons had few opportunities to compose argumentation. Except for the very few cases of argumentation, most of the students' answers in the three lessons were low-level recall and short utterance responses. This coincides with the characteristics of the IRE pattern (McNeill and Pimentel, 2010).

In conclusion, little argumentation took place in the three pre-service teachers' classrooms. Most of the questions raised by the teachers were closed questions and students have no opportunity to compose argumentation when faced with closed questions. All argumentation is prompted by open questions, but not all open questions in the classroom will bring about argumentation.

Table 6 Details of Open Questions in the Three Lessons

Teacher	Number of open questions	Sub-types and number of open questions	Followed with argumentation
Alice	6	Asked students to give examples (2)	No
		Asked students to describe the experiment they had observed (1)	No
		Asked students to explain (2)	Yes
Tina	7	Asked students to describe the experiment they had observed (3)	No
		Asked students to explain why (4)	Yes
Jane	7	Asked students to describe the experiment they had observed (1)	No
		Asked students to explain why (6)	Yes

Discussion and conclusions

As previously mentioned, argumentation is a relatively new word in science education, especially in Mainland China where few research studies have been conducted and published in the past. In this study, the three participating pre-service teachers were found to have limited understanding of argumentation in the area of science education. This lack of understanding of argumentation is evidenced by the fact that 1) they had limited understanding of argumentation; 2) they did not recognize the role of argumentation in scientific practice and had never heard of argumentation in science education; and 3) they did not consider the objectives related to argumentation in science education.

These three pre-service teachers showed different skills of composing argumentation. When the topic was related to their daily life, two of them showed relatively good skills. However, their daily argumentation levels were significantly higher than those of their scientific argumentation. When faced with scientific propositions, all three showed weak skills of argumentation. They were even reluctant to compose argumentation for those scientific propositions which have been widely accepted by others. Their responses hint that these pre-service teachers' views on science knowledge are relatively traditional. The findings of this study mean that two points should be addressed: one is that these pre-service teachers do have the potential to compose argumentation; another is that their traditional views on scientific knowledge may be an obstacle to their argumentation.

Corresponding to their limited understandings and skills of argumentation, the argumentation which took place in their lessons was obviously also very limited. The lessons given by these three pre-service teachers showed a typical IRE pattern with few open questions raised. As a result, little argumentation took place. In this study, we cannot say that lack of argumentation in the science classroom is solely a consequence of the science teachers' poor understandings and skills of argumentation. But we can say that this study shows that coherence exists in the pre-service teachers' understandings, skills and instructional practice. It also reminds us that the relationships between teachers' understanding, skills and instructional practice need to be further explored in the future.

Many factors may contribute to the pre-service teachers' limited understandings of argumentation. The limited amount of research published on argumentation in science education in Mainland China may be one of the significant factors that caused the pre-service science teachers to have never heard of argumentation in the area of science education before. There are also many factors leading to the lack of argumentation taking place in their classrooms. A systematic review to examine the weaknesses and strengths of the education system may be helpful to us in identifying the underlying reasons for this situation. At present, to introduce the international experiences of argumentation and to investigate the model which is relevant and suitable to the implementation of argumentation in Chinese science classrooms is a feasible road for science educators in Mainland China. However, directly introducing argumentation may cause many problems and may not necessarily bring the expected results. To carry out some localization studies with regard to argumentation would be meaningful.

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