International Journal of Science Education

ISSN: 0950-0693 (Print) 1464-5289 (Online) Journal homepage: http://www.tandfonline.com/loi/tsed20

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To cite this article: Yu-Ren Lin & Jeng-Fung Hung (2016) The analysis and reconciliation of students' rebuttals in argumentation activities, International Journal of Science Education, 38:1, 130-155

To link to this article: http://dx.doi.org/10.1080/09500693.2015.1134848

Published online: 22 Jan 2016.

INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, 2016
VOL. 38, NO. 1, 130–155
http://dx.doi.org/10.1080/09500693.2015.1134848

The analysis and reconciliation of students' rebuttals in argumentation activities

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ABSTRACT

The present study investigated the guidance provided by science teachers to resolve conflicts during socioscientific issue-based argumentation activities. A graphical representation (GR) was developed as a tool to code and analyze the dialogue interaction process. Through the GR and qualitative analysis, we identified three types of dialogue reconciling strategies. The first one consists of teacher management, in which the teacher temporarily maintains the right to speak when students get mired in an emotional rebuttal situation. The second strategy involves the use of qualifiers to identify the strengths and weaknesses of an opposing argument. The third strategy consists of providing students with guidance to keep both parties (i.e. the students taking, respectively, the affirmative and negative positions) on the same discussion topic and can be used to assist teachers with forming broad questions that prompt students to conduct deeper discussions. These reconciling strategies were beneficial in that they helped students to argue in a more reflective way.

ARTICLE HISTORY
Received 25 March 2014
Accepted 16 December 2015

KEYWORDS
Argumentation; rebuttal argument; reconciliation

Introduction

Argumentation is a key component of scientific literacy that has been emphasized in the field of science education in recent years (Clark & Sampson, 2008; Driver, Newton, & Osborne, 2000; Duschl & Osborne, 2002; Kuhn, 1993; Kuhn & Udell, 2003; Kuhn, Wang, & Li, 2011; Pontecorvo, 1993). Providing opportunities for students to participate in scientific argumentation requires involving students in the processes of knowledge evaluation and knowledge construction (Ford, 2008; Ford & Wango, 2012). However, previous research has indicated that most science teachers rarely engage students in scientific argumentation during class (Roth et al., 2006; Simon, Erduran, & Osborne, 2006; Weiss, Banilower, McMahon, & Smith, 2001). One possible reason for this is that teachers may believe that they have insufficient knowledge to engage students in argumentation discourse (Erduran, Simon, & Osborne, 2004; McNeill & Knight, 2013) or group discussions (Kuhn, Goh, Iordanou, & Shaenfiel, 2008; Sampson & Blanchard, 2012; Sampson & Clark, 2008). According to Toulmin's argumentation pattern (TAP) (1958), a sound argument is composed of six essential components: data, claim, warrant, backing, qualifier, and

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rebuttal. Kuhn (1991) investigated the responses that children and adults gave to questions concerning controversial social issues. Kuhn claimed that generating evidence-based and rational rebuttals is the most complex skill for the majority of students. One reason for this is that when students make a rebuttal, they not only need to justify their claims but also must recognize their limitations (Erduran et al., 2004; Garcia-Mila, Gilabert, Erduran, & Felton, 2013). This task is not easy for most students. In spite of the difficulty of generating an evidence-based rebuttal, however, students still can provide opposing views based on their personal opinions (Albe, 2008; Bell, 2004; Cavagnetto, Hand, & Norton-Meier, 2010; Hogan & Maglienti, 2001). Students tend to think that ‘persuading’ is the main goal in an argumentation activity (Berland & Hammer, 2012; Patronis, Potari, & Spiliotopoulou, 1999). Mercer (2000) used the term ‘disputational talk’ to describe this kind of dialogue interaction.

Researchers in science education agree that challenges, doubts, and rebuttals are essential for more in-depth discussions in both the scientific community and in the classroom (Sadler, Chambers, & Zeidler, 2004; Walker & Zeidler, 2007). However, providing appropriate guidance for students to learn about generating a reflective and evidence-based rebuttal is challenging (Jiménex-Aleixandre, Bugallo, & Duschl, 2000; Kuhn & Udell, 2003; Osborne, Erduran, & Simon, 2004). Asterhan and Schwarz (2009) suggested that teachers must pay special attention to the task of guiding students to generate rebuttal arguments. They found that students were likely to form a kind of ‘debate-type win–lose’ situation; that is, they typically sought to refute their opponents’ arguments and prove the superiority of their own arguments. Albe (2008) further indicated that

> when students expressed opposing views it can lead them to develop further explanations, to request one another to explain or support their claims and allow collaborative argumentation … Disagreements, on the other hand, could lead to contradictory confrontations: one student raises objections, questions or proposes an alternative and others disagree. In this case, opposite claims are expressed without further explanations or alternative proposals and it can cause the destabilisation of the object under discussion, sometimes resulting in its abandon. (p. 83)

Albe’s indications implied us that student’s rebuttals in argumentation could be a main reason to cause conflict and make the learning atmosphere unfriendly. Thus, rebuttals in the context of argumentation learning must be treated with care by teachers. Previous research has highlighted the importance of the guidance teachers provide when students engage in crafting rebuttals or otherwise disagree during argumentation (Garcia-Mila et al., 2013). The present study identified this kind of guidance as reconciling strategies that aim to facilitate the process of shifting from competitive (debate-type) argumentation to a more evaluative and reflective form of argumentation. The purpose of the present study was to investigate the possible reconciling strategies used in science classrooms and to explore how they support students’ argumentation. Specifically, it posed the following two questions:

(1) For a science teacher, what strategies can be used to reconcile the conflicts caused by students’ rebuttal arguments during argumentation activities?
(2) How do such reconciling strategies support students as they learn about scientific argumentation and improve their abilities to reflect on and evaluate their own arguments?

Theoretical framework

Although argumentation is an essential aspect of scientific thinking in education, several questions remain regarding how to help students understand how to argue scientifically and why argumentation is important. This study was particularly interested in processes students engage in when crafting rebuttals and the strategies that teachers can use to reconcile rebuttals during argumentation activities. This section attempts to unpack the main theoretical constructs related to learning and teaching argumentation and rebuttal in a science classroom.

Teaching argumentation in science classrooms

Argumentation is a part of the scientific practice of evaluating and establishing new theories and is considered a core element of the scientific enterprise (Duschl & Osborne, 2002; Jiménex-Aleixandre & Erduran, 2008). In science education, argumentation has long been considered an essential ability for achieving science literacy, and has drawn considerable attention in recent educational research (Boulter & Gilbert, 1995; Driver et al., 2000; Duschl & Osborne, 2002; Martins, Mortimer, Osborne, Tsatsarelis, & Jiménez-Aleixandre, 2001; Zohar & Nemet, 2002). Argumentation instruction involves learning 'reasoning about the advantages and disadvantages, pros and cons, causes and consequences, of alternative perspectives' (Mason & Scirica, 2006, p. 492). Jiménex-Aleixandre and Erduran (2008) indicated that learning argumentation supports the development of communicative competences and critical thinking, enhances the enculturation of scientific community, and empowers students to speak and write scientifically. Kuhn (2005) proposed a triangle model in which three elements are emphasized to explain what argumentation means and how people argue. The three elements are as follows: (1) one's own personal perspective, (2) other's perspective, and (3) external information. The first element represents someone's theoretical ideas or his/her unproved theories; the second refers to both supporting and opposing views; and the third refers to facts, pre-existing theories accepted by the community, or unproved theories supported by evidence. Kuhn emphasized that argumentation is a process of knowledge evaluation. The process of argumentation may even take place in an individual's mind; when one articulates a point of view, arguments are generated as an inner chain of reasoning. Alternatively, this process may take place among two or more people with opposing viewpoints on an issue.

Studies of learning argumentation have suggested that engaging in scientific argumentation could improve learners' understandings of the nature of science (Sandoval & Milwood, 2008; Simonneaux, 2008) and scientific knowledge (Jiménex-Aleixandre et al., 2000; Jiménex-Aleixandre & Pereiro-Munhoz, 2002; Mason, 1996; Zohar & Nemet, 2002), in addition to encouraging them to participate in scientific inquiry (Sandoval & Millwood, 2005). Although integrating argumentation into science learning helps students understand what science is and how it works, efforts to instruct students in argumentation have not always had successful outcomes. Zohar and Nemet (2002) studied 7th–9th grade students' discussions about moral dilemmas in human genetics. They found students that tended to form unwarranted opinions and ignore alternative points of view in discussion. Hogan (2002) found that 8th grade students usually use disconfirming evidence and rely upon uncritical statements for backing their assertions. Similarly, Sandoval and Millwood (2005) indicated that students usually cited data, yet often failed to cite sufficient evidence for claims when writing scientific argumentation. Cavagnetto et al. (2010) also found that most of the arguments made by students in the context of scientific discourse are related to claims and data, whereas students rarely provide rebuttals or counterclaims to challenge the proposed ideas. Moreover, most of the rebuttals made by students are just 'objections to ideas rather than fully developed rebuttals as characterized by Toulmin (1958)' (p. 440). In Clark and Sampson's (2005) study, students even used distorted data to support their idiosyncratic ideas. One reason for the limitations of teaching argumentation is that traditional science classroom practices do not promote the practice of argumentation (Bell, 2004; Erduran et al., 2004; Jiménex-Aleixandre et al., 2000). In order for science teachers to improve the practice of argumentation, researchers suggest that argumentation should be taught with explicit strategies (Zohar & Nemet, 2002) that consider students' knowledge backgrounds and emphasize a collaborative learning environment. Moreover, science teachers should believe that students of all academic levels have the ability to engage in argumentation activities that involve high order thinking (Zohar & Dori, 2003). Zohar (2008) indicated that the teaching of argumentation requires a change from the role of 'the teacher as an authority towards the role of the teacher as a facilitator' (p. 246).

A number of studies have used TAP to explain the structure and essential elements of sound argumentation (Chen & She, 2012; Clark & Sampson, 2008; Erduran et al., 2004). However, TAP has limitations (Jonassen & Kim, 2010). First, it is difficult to distinguish a warrant from a backing. Second, Toulmin's model considers only one side of an argument; the opposing side is ignored (Andriessen, 2006). These limitations prevent learners from developing multiple perspectives in argumentation activities and from making reflective and evaluative arguments (Schwarz, Neuman, & Biezuner, 2000; Voss, Tyler, & Yengo, 1983). For this reason, recent studies have paid greater attention to the dialectical form of argumentation, emphasizing knowledge evaluation, communication, and multi-voiced interactions (Driver et al., 2000; Jonassen & Kim, 2010; Van Eemeren, Grootendorst, & Henkemans, 2008). Dialectical argumentation refers to the process through which alternative claims are provided and resolved by convincing opponents (Jonassen & Kim, 2010) or compromising on multiple claims (Driver et al., 2000). The present study assumed that dialectical argumentation can provide more opportunities for students to learn how to argue. We therefore considered the argumentation process to consist of collaborative dialogue interactions which support the development of multiple perspectives on the given topic.

The meaning of rebuttal in argumentation

Toulmin asserted that rebuttals can function as a tool to indicate the exceptional circumstances in which 'the general authority of the warrant would have to be set aside' (1958, p. 101). Rebuttals can refer to the specific circumstances of defeating or rebutting the warranted conclusions. Pollock (1987) described a rebuttal as a form of 'defeasible reasoning'. He used the term 'defeater' and explained that a statement that could mandate the retraction of the conclusion constitutes a defeater. Pollock stated that there are two types of defeaters: rebutting and undercutting. Rebutting defeaters are used to attack an argument by undermining its conclusions. For example, an ornithologist named Herbert tells me that not all swans are white. In this case, discovering a black swan is a rebutting defeater to the conclusion. In contrast, if a student attempted to give an undercutting defeater, he/she might say, 'One of my reliable friends, Simon, told me, "Don't believe Herbert. He is incompetent."' Although Simon's remark constituted a defeater and gave a reason to withdraw his/her belief, Simon neither discovered a black swan nor was he an ornithologist. In other words, what the remark attacked was not the conclusion.

Toulmin and Pollock's work had significant effects on subsequent rebuttal studies. Verheij (2005) investigated the role and function of rebuttal in argumentation. Verheij divided rebuttals into five categories by analyzing the objectives of rebuttal attacks. The first three types of rebuttals attack the data, claim, and warrant, in that order. The fourth type of rebuttal attacks the connection between the data and claim. The fifth kind of rebuttal attacks the application of the warrant. Verheij believed that these five rebuttals would support teachers' understanding about the role of rebuttal in the development of scientific knowledge and also help them to teach scientific argumentation. Rather than considering rebuttals as a means of attacking others' opinions, rebuttals should be seen as one's recommendations for indicating the exceptional circumstances in which claims do not hold true. In this regard, the process of formulating a rebuttal is related to knowledge evaluation, an aptitude often found lacking among high-school and college students (Albe, 2008; Berland & Hammer, 2012; Hogan & Maglienti, 2001; Patronis et al., 1999; Zeidler, 1997). Students need guidance and scaffolding to learn what rebuttals are and how to generate rebuttals on the basis of their scientific knowledge (Noroozi, Weinberger, Biemans, Mulder, & Chizari, 2012; Osborne, 2010).

Rebuttal in argumentation learning

Studies have shown that students' dialogues in argumentation activities take many different forms. Mercer (2000) identified three types of dialogues that students usually use in discussions: disputational, cumulative, and exploratory. Disputational talk is characterized as challenges and exchanges of counterclaims. Cumulative talk involves students' agreements, confirmations, and elaborations. Exploratory talk is related to idea construction (i.e. one student constructs a point of view based on others' opinions). Following Mercer's (2000) research, Mork (2006) suggested that disputational talk deserved more attention from science teachers, because they need to manage students' dialogue interactions. Rebuttal in argumentation activities is often the main reason for disputational talk. Walton (1998) even described this type of talk as a form of eristic dialogue, or quarreling. Researchers found that most students have the ability to provide rebuttals and counter-arguments (Grace, 2005; Zohar & Nemet, 2002). However, these rebuttals tend to be simple, consisting of only one justification (Zohar & Nemet, 2002). Students even usually regard argumentation activities as a kind of competition. Albe (2008) investigated students' argumentation regarding socioscientific issues (SSIs), and found that some conflicts arise when students generate rebuttals and express disagreements. Moreover, students seldom consider others' challenges or rebuttals as positive or neutral comments; they tend to respond immediately and negatively when they were rebutted. Unfortunately, this kind of dialogue interaction is likely to cause conflicts, and does not benefit students in terms of argumentation learning. In this regard, it is important for science teachers to pay attention to the attacking argument to form a productive and positive learning atmosphere

(Albe, 2008; Asterhan & Schwarz, 2009; Sampson & Clark, 2011). Berland and Hammer (2012) indicated four possible reasons for explaining what causes dialogue conflict in science classrooms with the perspective of competing expectations. The first reason they suggested was competing expectations regarding the objective of argumentation. Should the learning objective be to improve the participants' understanding of the scientific knowledge, or for the participants to persuade the other participants to accept their opinion? The second reason they suggested was competing expectations regarding who can dominate the topic of discussion, while the third reason they suggested was competing expectations regarding who can provide the sources to support or oppose someone's ideas, that is, teachers or students. The fourth reason they suggested was competing expectations regarding how ideas would be validated, such as by an authority or according to empirical evidence. Baker, Bernard, and Dumez-Féroc (2012) used the term 'broadening and deepening the debate' to describe the possible themes for expanding argumentation activity. These studies suggested to us that the conflicts in argumentation activities need to be coordinated, and that science teachers should purposely guide interactions in the classroom so that they are more reflective and rational, and more clearly based on the scientific knowledge.

Studies of written arguments have found that the goal of a task has an effect on the quality of an individual's written argument (Ferretti, MacArthur, & Dowdy, 2000; Nussbaum & Kardash, 2005). Ferretti et al. (2000) indicated that the goal 'to persuade' is appropriate for stimulating adversarial discourse while the goal 'to produce claims, counterarguments, and rebuttals' is appropriate for improving reflective discussion. Osborne (2005) found that the goal 'to persuade' may undermine the quality of arguments and lead individuals to suppress alternative claims and evidence in their writing because students fear that they will undermine the persuasive strength of their essays. Similarly, when arguing in dialogues, students may explore less deeply and use less evidence if the goal is to persuade (Keefer, Zeitz, & Resnick, 2000; Nussbaum, 2005). A number of educators have indicated that challenges, doubts, and rebuttal arguments are essential in both the scientific community and in the classroom because they provide opportunities for knowledge evaluation and reconstruction. Other educators believe that generating evidence-based and rational rebuttals is a complex skill, and suggest that teachers must pay special attention to these challenges and disagreements. The present study integrated both of these positions and asserts the need to explore what teachers can do to scaffold students' argumentation learning so that the arguments they produce will be more reflective in nature. We defined this kind of scaffolding as reconciling strategies and then explored possible reconciling strategies through the analysis of two teachers' argumentation teaching.

Method

Participants

This study was conducted at a college in southwestern Taiwan. Our research took place during the summer of the year during which the college's science teachers had voted for the teaching of inquiry and argumentation to be the focus of their professional improvement efforts. Most of the curriculum relevant to science at this college therefore had an inquiry-based and student-centered design. Among the five science teachers at this college, only two of them, Jack and Linda, were experienced in teaching argumentation, held master's degrees, and had written theses related to teaching argumentation. We therefore invited them to join our research team. Both teachers expressed their interests in teaching argumentation and agreed that student conflicts in argumentation should be reconciled. Although Jack and Linda were almost the same age and were both science teachers with a master's degree, they had different perspectives on classroom instruction and their strategies for teaching argumentation were quite different. Linda had had seven years of experience in teaching science when she was invited to join our research project. She emphasized organization and discipline in her classroom, and usually used traditional strategies to teach science during her first four years. However, she changed her teaching style gradually. During the research semester, Linda taught science with a student-centered instructional approach. She emphasized collaboration among the students, as well as their prior knowledge, and encouraged them to explore related information from multiple resources, such as the internet and libraries. Jack, the other science teacher on the team, had had three years of experience in teaching science before participating in our research project. He enjoyed an open and less-formal learning environment and believed that students' participation in scientific argumentation would improve both their understanding of scientific knowledge and their understanding of the nature of science. The students in Jack's science classroom were encouraged to share and test their ideas by conducting scientific experiments. Although Linda had much experience than Jack in teaching science, Jack had considerable experience in teaching argumentation. We viewed Linda as a beginner in that regard, while Jack clearly had more experience in teaching argumentation specifically. We expected, then, that their teaching could effectively represent different phrases of professional development in argumentation teaching. Importantly, they also provided us with more opportunities for broadening the range of teaching data. Linda and Jack were each responsible for teaching one science class in the college. In total, then, two 10th-grade classes totaling 98 students (92 females and 6 males) majoring in nursing participated in this study. All the students had no prior experience in participating in any research projects, and most of them came from middle-income homes. To improve the students' argumentation skills, both the teachers explained the basic elements of a sound argument to their students in the first and second lessons.

Argumentation activities

The scenarios featured in the argumentation activities were related to SSIs. Using SSIs as topics for teaching, argumentation has been suggested as being beneficial for students in terms of practicing how to argue scientifically and for their understanding of the related scientific knowledge (Dawson & Schibeci, 2003; King & Kitchener, 2002; Patronis et al., 1999; Yang & Anderson, 2003). There were two SSI scenarios developed for both teachers' argumentation teaching. The first scenario related to the use of surfactants, and the second scenario involved cosmetics and health. Both SSI scenarios were developed based on the content of the school's science curriculum, the students' prior knowledge, and the students' motivations. To improve the students' abilities to use scientific knowledge in crafting backings for their arguments, we provided both teachers with a brief introduction to the two SSIs before they began their instruction of the students. Moreover, we also designed an argumentative question for each introduction to facilitate the generation of counter-arguments and alternatives. These introductions and questions were as follows:

- *The use of chemical surfactants*: Surfactants are compounds that lower the surface tension of a liquid. The most familiar uses of surfactants are their inclusion in soaps, laundry detergents, dishwashing liquids, and shampoos. Chemical elements are usually added to these products to provide a variety of functions, such as increasing cleaning performance and ensuring product stability. However, those elements may damage both our skin and the environment. Research has found that most surfactants are more or less toxic to aquatic organisms due to their surface activities, which can cause them to react with the biological membranes of the organisms. Would you support the use of chemical surfactants in our daily life? Why or why not?
- *Cosmetics and health*: Cosmetics (colloquially known as makeup) are substances used to enhance the appearance or odor of the human body. However, some scientists have reported that some of the ingredients in cosmetics and personal care products may be hazardous to your health. While cosmetics and personal care products are made up of a number of ingredients, some are made with organic materials. Many people believe organic and environmentally friendly ingredients are better for our skin, but the truth is that this belief has no scientific legitimacy. Do you agree that cosmetics products are necessary in our daily life? Why or why not?

The following steps explain how the two teachers carried out the argumentation activity for each SSI topic: (1) introduce the students to the SSI scenario; (2) ask the students to collect related information from libraries or the Internet, or via interviews with their parents, friends, teachers, or experts in biology, chemistry, or other relevant areas; (3) ask the students to organize the information that they collected, to generate arguments in response to the argumentative question, and to reflect on possible counter-arguments; and (4) hold a role-play debate activity in which all the students address their positions and counter-positions, in addition to assessing alternatives. The idea of holding a role-play debate activity was based on suggestions in previous studies regarding argumentation and role-play debates (Foong & Daniel, 2013; Molinatti, Girault, & Hammond, 2010; Simonneaux, 2001). First, a heterogeneous grouping was used. The students chose their team members, and the teachers asked that the size of each team be in the range of five to six students. Second, each student could choose to be a leader (speaker), assistant, or recorder for their team. The team leader was in charge of making arguments. The assistant was in charge of collecting and organizing data and giving ideas to the leader. The recorder was responsible for recording the important statements generated in the debate. Third, each student team member was assigned one of the careers to broaden the topic of discussion. The assigned careers included economist, politician, ecologist, and doctor. Before the role-play debate activity, the students worked collaboratively to decide whether to be an affirmative team (i.e. a team that supported using cosmetics and surfactants in daily life) or a negative team. Afterwards, each student team collected and organized related information according to their career, and determined the connection between the information and their arguments. Debate was opened with the given affirmative speaker presenting his or her team's arguments, after which the negative speaker responded. This pattern was repeated for the second speaker in each team. Finally, each team got an opportunity to rebut the arguments of their opponents. The teacher remained neutral, leaving the students to take up the various points spontaneously.

Coding framework

We developed a graphical representation (GR) as a tool for coding and analyzing the students' arguments. Briefly, the GR is a pattern composed of a series of symbols that represent different kinds of arguments (see Figure 1). We coded every argument generated by the students and teachers into the GR, which allowed us to analyze the process of student argumentation systematically. Moreover, the GR enabled our analysis to focus more on when the students provided a rebuttal, on what the rebuttal was based, and how the teacher reconciled the dialogue conflicts caused by the rebuttal. Developing the GR involved three stages: selecting its elements, designing a structure, and using symbols.

First, we selected three essential elements based on the discussion of TAP in the literature review: assertion (A), warrant (W), and rebuttal (R). In order to reduce the complexity of the GR, and in order to have a better representation of the dialogue interactions during the argumentation, we used a number of symbols to indicate additional important elements emphasized in TAP. For instance, we coded a qualifier into a link between the warrant and rebuttal based on Sampson and Clark's (2008) display of a qualifier marked as a link between two opposite views. A link between elements shows the argument generation process. For example, one student generates a warrant based on an assertion proposed before; we thus drew a line, starting from an 'A', to a 'W' in the GR system. Second, to design the GR structure, we drew upon Roth's (1997) study, in which he designed a GR for coding student dialogue interactions based on the structure of bi-dimensional space. Roth's GR was organized around two axes: the *x*-axis running horizontally represented time and the *y*-axis running vertically represented the content of a student's statements. Note that the part above the *x*-axis indicates dialogue interactions on the affirmative side/position. On the other hand, the part below the *x*-axis represents the negative side. The last phase of designing the GR involved using coding symbols. Three kinds of symbols (○, □, and △) were chosen to represent opinions, questions, and rebuttals, respectively. Ten commonly seen symbols of GR in our data analysis are presented in Figure 1 to explain how we coded students' dialogue argumentation. Table 1 provides further details on what is shown in Figure 1.

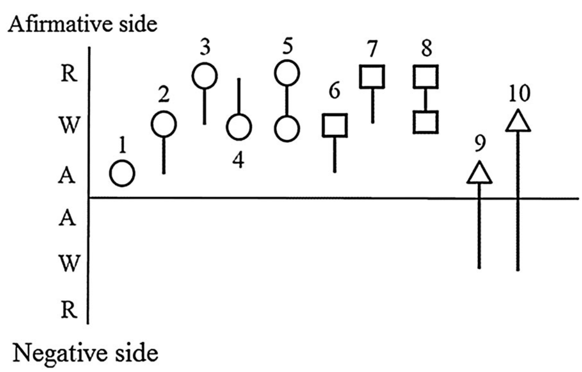

Figure 1. Symbols of generating dialogues (from 1 to 5), questioning dialogues (from 6 to 8), and rebutting dialogues (from 9 to 10) in GR.

In order to distinguish a teacher's statements from the students' statements, dashed lines were used to specify statements made by a teacher, and solid lines were used for the statements made by students. We also used the color black to distinguish high-quality arguments from low-quality arguments. For example, the symbol ▲ represented high-quality rebuttals, and the symbol △ was used for low-quality rebuttals. Similar to several other studies, we evaluated arguments based on three criteria (Clark & Sampson, 2008; Erduran et al., 2004; Hogan & Maglienti, 2001; Yeh & She, 2010). First, is the argument logical, rational, and coherent, and does it include an explanation or state the source of authority supporting the position? Second, does the argument contain relevant scientific theories or concepts? Third, is the argument based on empirical evidence and life experience? If an argument met at least one of these three criteria, it was categorized as high-quality; otherwise, it was categorized as low quality. The criteria we used in this study contained only two levels, and were thus simpler than the criteria used in previous studies; we believe this design allowed the analysis to focus more on the process of argumentation.

Data collection and analysis

The main data in the present study were the dialogue interactions in four 40-minute role-play debate activities (each teacher had two debate activities). All the debate activities were videotaped and the dialogue interactions were coded into the GR. In order to explore the strategies used by each teacher to coordinate the students' rebuttal arguments, the transcripts from all the learning activities were read line-by-line by the first author and the given teacher. Any off-task portions of the conversation in the transcripts were removed. In order to obtain clearer explanations of the reconciling strategies used by

Table 1. Definitions of three types of utterances: Opinions, questions, and rebuttals.

No.	Definition	Dialogue example
1	Making an assertion	I agree with the idea that people should use chemical surfactants
2	Making a warrant to support the assertion	I agree with that, too, because surfactants are important for cleaning, and people use them almost every day
3	Making a rebuttal after considering the warrant	Although surfactants are important for cleaning, most of them have toxic effects on some (aquatic) organisms, and we should take note of this
4	Making a warrant after considering the rebuttal	We know that some surfactants are toxic, and therefore, we should choose organic or and environmentally friendly surfactants rather than chemical ones
5	Making a qualifier to identify the conditions under which the warrant is prohibited	There are various types of surfactants, each with its own merits, and we should know when we can use chemical surfactants and when we should use natural ones
6	Question for warrant to support the assertion	What is your reason for supporting the assertion?
7	Question for rebuttal after considering the warrant	We already know that some surfactants are toxic; however, what should be considered when we purchase a detergent at the market?
8	Questions for broadening the discussion to a new knowledge base	What is the chemical composition of surfactants? How does a scientist explain the chemical reactions involved in a dissolving process?
9.	Making a rebuttal to criticize an opponent's assertion	Using chemical surfactants for clearing is immoral, because doing so will pollute our environment
10.	Making a rebuttal to criticize an opponent's warrant	You are wrong because not everyone uses chemical surfactants every day, and we can replace the chemical type with the natural kind

the given teacher, each 40-minute debate activity was separated into a series of episodes, or 'smaller units of coherent interactions within events' (Jordan & Henderson, 1995, p. 57) for further analysis. After careful discussion among the members of our research team, we selected the one episode that best demonstrated each strategy for reconciling the conflicts during the argumentation activities. The coding of the GR was accomplished by two researchers (the first author and a science teacher with a master's degree), and the coding reliability was 0.89. All disagreements were resolved through further discussion. The pattern of the GR was important in laying the ground work for understanding how the students used arguments for justification and how the teachers provided strategies for reconciling rebuttal arguments. Table 2 and Figure 2 illustrate how the GR was used to code the dialogue interactions from the argumentation activity.

In our coding strategies, we first analyzed the purpose and content of the target argument, and then selected the specific symbols with which to code the target argument in the GR. In this discussion sample (Table 2), the students were discussing the question, 'Do you agree that people should use chemical surfactants?' The first statement was a question provided by the teacher (No. 1). Statements No. 2 and 3 were the students' responses to the question. We categorized these two students' statements as opinions, including one assertion and one warrant in the GR coding (Figure 2), and represented them with the symbol '○'. Because student A provided several examples of surfactants and their uses in daily life, statement No. 3 was coded as a high-quality warrant. One rebuttal (No. 4) was generated in the following discussion based on the consideration of the environmental pollution issue. That issue served as a warrant for the negative side, and student B used it to rebut the warrant provided by student A. Thus, the coding process in the GR used the triangle symbol from the place of warrant in the negative side to attack the warrant in the affirmative side. The following statements showed how a teacher might generate a qualifier for reconciling the rebuttal, and how we coded those dialogues in the GR. In the beginning, the teacher agreed that some detergents are toxic although they are daily necessities (No. 5). The statement was generated based on the warrant in the affirmative side (No. 3), indicating that it is risky to use unknown surfactants. The statement the teacher provided was actually a rebuttal on the affirmative side. Thus, the coding of this statement refers to the generation of a rebuttal on the affirmative side. We then used '○' symbols in the W and R positions on the affirmative side. In the end, the teacher provided an idea to reconcile the conflict,

Table 2. Teacher-student discussion sample.

No	Speaker	Time (s)	Statement	Side	Quality	Utterance
1	Teacher	1–3	Do you agree that people should use chemical surfactants?	Neutral	Low	Question
2	Student A	5–6	I agree	Affirmative	Low	Opinion
3	Student A	6–21	Because it is necessary in our daily life. Many cleaners that we use in our daily lives, such as detergents, soaps, or washing liquids … they are kinds of surfactants	Affirmative	High	Opinion
4	Student B	22–30	It is wrong to use surfactants that will pollute our environment	Negative	Low	Rebuttal
5	Teacher	31–34	He is right, some detergents are toxic	Affirmative	Low	Opinion
6	Teacher	35–55	After consideration of your opinions, I think the selection is important; for example, we should use natural detergents to clean our bodies …	Affirmative	High	Opinion

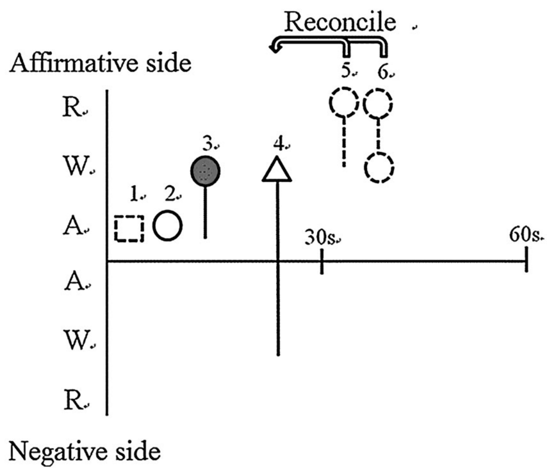

Figure 2. The GR of dialogue interactions in Table 2.

specifically, 'we should use natural detergents to clean our bodies' (No. 6). This reconciling statements referred to both the rebuttal (some detergents are toxic) and the warrant (detergents are daily necessities) on the affirmative side. Therefore, the coding process in the GR used two '○' symbols in the rebuttal and warrant positions on the affirmative side.

To categorize the strategies used by teachers for coordinating the rebuttal arguments, the principles of the emergent coding approach in content analysis were applied (Haney, Russell, Gulek, & Fierros, 1998; Miles & Huberman, 1994). In the present study, the analysis was focused on the rebuttal arguments, and the statements for reconciliation. Through the GR, we could see which arguments were rebuttal arguments, and when they were proposed. We could then also easily see which statements followed the rebuttal arguments and analyze whether or not those statements were related to the rebuttal arguments. The analysis was qualitatively based and consisted of three aspects: the purpose, the subject, and the manner of speaking. In the sample of Table 2, the teacher's agreement (No. 5) was defined as a statement for reconciling the criticism provided by student B (No. 4). Following the agreement, the teacher used another statement (No. 6) to strengthen the reconciliation. Furthermore, the main theme of the two statements (i.e. No. 5 and No. 6) was the same as the criticism student B provided (i.e. the statement regarding the need to protect the environment). In contrast with the student's rebuttal, however, the teacher tried to remain neutral and to prevent a conflict between the two students. Thus, we regarded the two statements as having been used for reconciliation. After identifying the argument and the statement used for reconciliation in each episode of argumentation, we used hollow arrows to mark their relationship. The pointed end was the rebuttal, and the starting end was the statement of reconciliation (Figure 2). All the rebuttal arguments and statements for reconciliation were carefully reviewed by the two authors after they were identified. The reviews were focused on the strategies used by the teachers for reconciliation, and also looked at how the teachers guided the students to avoid dialogue conflict and to construct arguments based on scientific knowledge or empirical experience. Rather than using preconceived categories for exploring the teachers' strategies, we found the themes or issues that recurred in the text and these became our categories.

Results

Three types of strategy for reconciling rebuttal arguments were identified in our investigation. The following analyses and episodes explain the process of how a rebuttal argument was proposed and then reconciled. The corresponding GR patterns are provided in Appendices 1 and 2.

Teacher's management

Episode 1

1. Elva:	We don't agree with people using surfactants.
2. Claire:	I think it will pollute our environment.
3. Ben:	No! We have wastewater treatment plants; wastewater will pass through it before flowing into the ocean.
4. Elva:	How could it be possible for a wastewater treatment plant to deal with wastewater from all families and factories? … ok?
5. Daisy:	It is possible. If you don't think so, you can ask our government to shut it down … ok?
6. Linda (Teacher):	OK! Wait a second! Do not ridicule your classmate. I think the wastewater treatment plant is useful …
7. Linda (Teacher):	Someone give me some new opinions or evidence.

In the beginning of this episode, Elva, a student who did not agree with people using surfactants, generated a low-quality rebuttal (No. 4) to oppose Ben's point of view. The rebuttal caused a dialogue conflict and led Daisy, an opponent of Elva, to propose another low-quality rebuttal (No. 5). The teacher, Linda, noticed this dialogue conflict. She temporarily withdrew the students' right to speak (No. 6) and then encouraged the students to share their opinions again (No. 7). The dialogue interactions from No. 1 to 6 indicated to us a number of potential situations in which a teacher might need to withdraw the students' right to speak and reconcile the students' low-quality rebuttals: (1) when rebuttals are proposed consecutively, (2) when rebuttals are emotional, personal, and not based on any scientific evidence or theory, (3) when a student cannot propose any response to the rebuttal argument, and (4) when the argumentation is being dominated by a few students and not being joined by others in the class. Episode 2, continuing from Episode 1, shows how the teacher guided the students to argue with evidence.

Episode 2

8. Wen:	Recent newspaper reports have stated that people will go bald if they use low quality shampoos.
9. Linda (Teacher):	OK! That is important information. Does anyone on the affirmative side have a response to this argument?
10. Sue:	Not everyone is bald.
11. Wen:	What if you lose your hair after you use a low quality shampoo?
12. Sue:	I never use low quality and cheap shampoo.

13. Wen: A low price does not necessarily mean that a product is low quality … be smart.

After the teacher reconciles the conflict by managing the dialogue interactions (No. 6), the topic of discussion changed from environmental pollution to skin problems (baldness). What the teacher expected was that the students could use empirical evidence or data that they had collected from the library or Internet to generate arguments. However, the dialogue interactions in Episode 2 indicated that her expectation did not match the outcome. Following the teacher's encouragement, Wen proposed a well-founded argument. Nevertheless, after Sue's rebuttal, Wen proposed another low-quality rebuttal and the topic was changed again from skin problems to price of the product (No. 13). According to our analysis, one reason may explain Wen's statements, and why she had to change the talking topic. That is, she tried to avoid the dialogue conflict caused by the topic being discussed. We termed this kind of argumentation feature as topic-changing tendency, and it was common in our transcripts of student argumentation. In our further analyses, the topic-changing tendency may make students' argumentation fragmented, and most of the fragmented discussions were of low quality and not based on scientific evidence or theory.

Another factor causing low-quality argumentation is that students often generate arguments by following the structure of a previous statement (No. 10 and 11). Students will mimic the way that other students make arguments, especially for generating low-quality arguments. For example, the low-quality rebuttal Sue provided (No. 12) prompted Wen, usually a reasonable student, to generate another low-quality rebuttal (No. 13) even though Wen knew how to generate high-quality arguments (No. 8). The students would often imitate the strategies used by their classmates when generating arguments. In this case, the imitation was limited to the generation of a low-quality argument because we found that Sue did not follow Wen's strategy of generating well-founded argument. Thus, we thought that the strategy of reconciling through teacher management was temporary. That is, it could be used to reconcile students' emotional rebuttals, but only for limited time.

Reconciling by using a qualifier

In contrast with the first strategy discussed above, the second one, 'reconciling by using a qualifier', is much more thorough. To reconcile a conflict caused by a knowledge-based rebuttal, the strategy of using a qualifier focuses on identifying different situations for evaluating the validity of the arguments for both positions on the SSI.

Episode 3

14. May: A scientific paper indicated that some chemical surfactants like sodium lauryl sulfate are toxic. That surfactant is always found in cheap cleaning products. It will damage our skin …

15. Linda (Teacher): Are all chemical surfactants toxic and damaging to our skin? (Some quiet voices from the students answer in the affirmative position: 'Don't buy cheap products … ')

16. Cherry:	Some surfactants are toxic and damage our skin.
17. Carrie:	Yes, some surfactants are toxic; however, some surfactants are made with natural materials and cause little damage to our skin.
18. Sue:	Natural soap. My family uses it to clean the body. I even know some natural ingredients, such as avocado oil. It contains large amounts of vitamins A, D, and E, protein …
19. Linda (Teacher):	Thank you, Sue. As we know, using chemical surfactants may be unhealthy, but they are cheaper and more effective at removing stains. The question is: How do we use the different types of surfactants in different places?
20. Linda (Teacher):	The chemical surfactants are still useful because they are effective cleaners. When should we use chemical surfactants and when should we use natural ones?
21. Don:	I would choose natural surfactants for cleaning our bodies, especially for little babies.
22. Sue:	And the chemical surfactants can be used to clean cars and bathrooms.

In the beginning of Episode 3, May identified a surfactant, 'sodium lauryl sulfate', and generated a rebuttal. May's rebuttal was based on evidence (a scientific paper). The GR of this episode shows that May's statement contained a high-quality rebuttal and that was reconciled during the discussion (see the Episode 3 GR in Appendix 1). In the analysis of the teacher's reconciling process, we found that the teacher's three guidance questions (No. 15, 19, and 20) were related and layered. The purpose of these questions was to reconcile May's rebuttal. The first question, 'Are all chemical surfactants toxic … ?' was important to keep the discussion on the topic of skin problems (No. 15). The second question, 'How do we use the different types of surfactants in different places?' enabled the students to reflect on the application of different kinds of cleaners. The third question, 'When should we use chemical surfactants … and when should we use natural ones?' clearly explicated that there are many kinds of cleaners, and that each has its strong points. The layered questions enabled the students to co-construct their knowledge of surfactants and helped them form a qualifier to reconcile May's rebuttal. The purpose of using a qualifier is to identify the different situations for both positions. In this case, the teacher guided the students to reflect on the uses of surfactants and to reconcile the dialogue conflict. Some suggestions for how science teachers can know when a qualifier should be used to reconcile dialogue conflict in argumentation activities include the following: (1) when a high-quality rebuttal is provided. Different from controlling students' right to speak, a qualifier can be used to reconcile a well-founded rebuttal argument. (2) When there is an obvious lack of consensus among the people involved in the discussion. In Episode 3, students in the affirmative position could not provide any equivalent response after May's statement; instead, they only made low-quality rebuttals, for example, 'Don't buy cheap products.' In this case, neither position reached a consensus during the discussion. At that point, the teacher provided guidance questions to lead the discussion in a proper direction.

Reconciling by forming broad questions

In our data analysis, the two teachers usually applied the same strategy to form a broad question for reconciling students' dialogue conflicts. This strategy was defined as reconciling by forming broad questions, and it consists of two parts: (1) paying attention to how students use scientific knowledge, evidence, and theories as backings for their assertions and (2) giving guidance to broaden the debate scope to another learning activity. Episode 4 provides an example of how a teacher reconciled the dialogue conflict by using the first part of the strategy.

Episode 4

23. Tina:	I don't agree with using cosmetics. Many women are born with beauty and they have no need to use cosmetics.
24. Dyne:	You mean you were born with beauty?
25. Teacher (Jack):	Listen! Please don't talk about someone's appearance. Our discussion should be focused on the use of cosmetics and their ingredients.
26. Teacher (Jack):	What kinds of ingredients have bad influences on our skin?
27. Joe:	Toluene. It is found in nail polish and endangers our health, and it is a kind of endocrine disrupting chemical.
28. Teacher (Jack):	You mention toluene. Do you know why we (i.e. the manufacturers) add toluene to nail polish? Can you give me a scientific explanation?

In Episode 4, the teacher pays attention to the term 'toluene' in Joe's statement because he mentioned a chemical/scientific term. The teacher tried to avoid the original topic involving conflict and emotion (No. 24) and focused on the topic which is more rational and scientific knowledge-based (No. 27). Thus, he asked the students to provide more scientific explanations regarding the function of toluene in cosmetics (No. 28). It is common for students to use a scientific term to defend their opinions against rebuttals. However, in our analysis, most of the scientific terms used in students' statements were not explained in detail. Teachers should provide guidance to engage students in deep discussions regarding any scientific terms mentioned in their arguments that are still unclear. In this episode, the teacher's guidance led the argumentation to be more focused on the effects of certain ingredients on our skin. It broadened the debate activity to a kind of idea-sharing discussion, and also reconciled the dialogue conflict between Dyne and Tina.

Episode 5

29. Ann:	I found many science reports on the Internet, and they indicated that chemical surfactants will damage our skin seriously, they said … (reading her note book and criticizing the students in favor of using surfactants).
30. Teacher (Linda):	OK! Listen to me! So far our discussions have been related to health and the environment. Do you know what we can do and how we can reduce the use of surfactants?

31. Teacher (Linda): Take cleaning windows for example; if we clean them every day, it may be unnecessary for us to use cleaners.
32. Daisy: If we use old newspapers to clean windows, we could save on the use of cleaners.
33. May: Why? We always use rags to clean them.
34. Daisy: Because most of the ink used in newspapers is oily ink and it helps to clean the dirty oil on windows.

In Episode 5, Ann expressed her disagreement about using chemical surfactants by generating a rebuttal based on scientific reports and evidence (No. 29). To reconcile Ann's rebuttal, the teacher provided a question that helped the students on the affirmative side to reflect on what could be done to reduce surfactant use. In our analysis, the question proved to be an effective method of turning a rebuttal argument (No. 29) into a discussion of idea sharing and exploring scientific knowledge (No. 32, 33, and 34). The symbols in Episode 5's GR reveal a number of high-quality features (see Appendix 1). These features show that providing broad questions is an effective strategy not only for reconciling dialogue conflicts, but also for improving students' ability to generate high-quality arguments.

Discussion

Improving for in-depth argumentation

The present study investigated two science teachers' strategies for reconciling conflicts during argumentation activities. The reason to reconcile the conflicts is that students tend to provide arguments based on their personal opinions and rarely consider argumentation to be a kind of knowledge evaluation activity (Bell, 2004; Cavagnetto et al., 2010; Thomas, 2002). To provide opportunities for students to engage in in-depth argumentation, we paid attention to how dialogue conflicts were caused, and explored what can be done by teachers to reconcile such conflicts. Through the GR, an instrument we developed to code and analyze the students' arguments, we found that rebuttal arguments can be divided roughly into three main classes: rebuttals consisting of personal attacks, rebuttals consisting of personal opinions, and rebuttals consisting of scientific evidence. These categorizations were underlying our awareness of the strategies suggested for reconciling rebuttal arguments in the results of the present study. The first type of rebuttal, the 'personal attack', would be a main cause of dialogue conflicts among the students. In Pollock's theory, this type of rebuttal belongs to the 'undercutting defeater' (1987). It is used to attack the person making a statement rather than the situation or the statement itself. To reconcile a conflict caused by a rebuttal consisting of a personal attack, we suggested that teachers should explain what kinds of rebuttals qualify as personal attacks, and what kinds do not. The teacher may withdraw the students' right to speak temporarily, and then ask them to give positive recommendations after they know that personal attacks would influence their argumentation to be more emotional than rational. Although scientific argumentation is a specific type of persuasion dialogue, a main goal here is not to cause dialogue conflicts, but to solve them by means of rational dialogue interactions (Walton, 1998). Another reason to the necessary of the reconciliation of personal attack is that it cannot help students to understand the talking issue more; sometimes, it makes the argumentation off-topic. For instance, Wen changed the topic of discussion from environmental pollution, which was brought up by Claire, to the issue of skin problems (i.e. baldness) after Daisy's rebuttal consisting of a personal attack in Episode 1.

Besides the fact that rebuttals consisting of personal attacks can hinder student argumentation, the students may still become locked in a stalemate even though they know how to back up their assertions with evidence and reasons. In Episode 3, May quoted a statement from a scientific study when disagreeing with the idea of people using chemical surfactants. One of her classmates, Sue, criticized May's opinions based on her prior experience and personal investigation. In our analytical framework, both Sue's argument and May's argument were well-founded, rational, and no longer consisted of personal attacks. Specifically, May's rebuttal attacks the warrant (not every chemical surfactant is a low-quality product) of the affirmative position. This rebuttal is a typical rebuttal argument in Verheij's (2005) theory. After May's rebuttal, all the students were silent until the teacher provided further guidance. This case caused us to conclude that even if students have the ability to craft rational rebuttals, the argumentation may be still slowed down. To animate the students' statements, the teacher stated a question to help the students realize under what conditions the strength of their arguments would be limited, or the circumstances under which they might even be untrue. Then, the discussion was activated and the topic was turned back to a reflection on how we use different types of surfactants in different places. In our analysis, the question proposed by the teacher was a qualifier and it reconciled the students' dialogue conflict. Toulmin's theory reminds us that arguments are generally expressed with qualifiers rather than asserted as absolutes (1958). The qualifier lets students know how to take the reasoning, and how far it is meant to be applied. When teaching argumentation, a teacher should illustrate how to use qualifiers in the construction of an argument. As previous studies have suggested, using typical sentence patterns and phrases would be beneficial, such as 'usually', 'virtually', 'it depends', 'before we make', 'we have to know', etc. (Chen & She, 2012; Noroozi et al., 2012). Different from the other two strategies for reconciling students' dialogue conflicts, the third strategy, 'reconciling by forming broad questions', conveys a principle emphasized in previous studies that argumentation goes beyond a mere debate in the classroom (Jiménex-Aleixandre & Erduran, 2008; Kuhn, 2005). The purpose of the strategy is to extend students' classroom debates to other learning activities such as inquiries, literature reviews, and experiments. It clarifies for students what is still unclear in their arguments, where they can explore additional related information for backings, and how to carry out experiments for correcting key pieces of evidence. Rather than encouraging students to simply win debates, science teachers should broaden a debate by providing opportunities for students to construct their arguments through multiple scientific activities.

Multiple perspectives on rebuttal arguments

Rebuttals are arguments used to address potential objections, counter-examples, and exceptional circumstances to the claim (Toulmin, 1958; Verheij, 2005). In the development of a scientific theory, rebuttals can be used to indicate what is insufficient in the conclusion or argument (Kuhn & Udell, 2003). The purpose of a rebuttal is not only to challenge opposing opinions. Importantly, it also includes understanding possible limitations to any claims (Jiménex-Aleixandre et al., 2000; Osborne et al., 2004; Sadler et al., 2004; Walker & Zeidler, 2007). However, in the present study, we found that students often attempt to simply persuade their opponents and regard this to be the main purpose of argumentation. Thus, they sometimes express disagreements emotionally, change the topic under discussion, and ignore the use of scientific knowledge. These findings are similar to those of previous studies that have indicated that the teacher, as the social and epistemic authority, should provide appropriate interventions and manage students' argumentation (Berland & Hammer, 2012; Patronis et al., 1999). For this purpose, we offer a new perspective on low-quality rebuttal arguments (e.g. personal attacks) based on our analysis. Through the GR, we found that rebuttal arguments have positive influences on students' concentration. When a low-quality rebuttal was generated, the 'wait time' between the rebuttal and the next argument was short, requiring only about 1–4 seconds for another student to answer back. However, when a high-quality rebuttal was proposed, it took longer (about 5–12 seconds) for a response. Thus, we have an idea that the presence of low-quality rebuttals may attract students' attention and stimulate student discourse (Ferretti et al., 2000). For example, considering that 'beauty' is one of the topics of greatest concern among young people, a teacher could use the question 'Is there any relationship between using cosmetics and beauty?' to motivate students when a discussion is not moving forward. Although such a question may provoke many personal arguments, we found it was quite easy for most of students to engage in the discussion. We agree that generating evidence-based arguments is not easy for most students (Erduran et al., 2004; Kuhn, 1991). However, simply engaging students in argumentation can be regarded as a first step in the development of that skill.

One interesting finding yielded by the GR analysis was that students tend to imitate the ways in which their peers construct arguments. Specifically, the production of a low-quality argument would facilitate the production of another low-quality argument. An example of imitation in producing a low-quality argument was shown in Episode 1. We provided another example to show imitation in producing a high-quality argument. In Episode 3, May made an evidence-based rebuttal to show her disagreement with using surfactants. Two of May's opponents, Carrie and Sue, co-constructed an evidence-based argument to respond to May's point of view. The feature of imitation in student argumentation corresponds to what Gilbert (1997) describes as 'coalescent argumentation', in which students construct and negotiate a shared understanding in argumentation. A prior argument influences a subsequent one. This feature implies that a teacher has to set an example of how to construct an evidence-based argument for students to follow. Another feature of student argumentation we found was that students often changed the topic of discussion after they or their statements were rebutted. For example, in Episode 2, the original topic of discussion was the possibility of illnesses being caused by the use of surfactants. However, it was changed to the price and quality of surfactants after Sue's low-quality rebuttal. This finding supports the indications of previous studies that students do not understand what the objective of argumentation is, and they tended to generate arguments unrelated to the topic being discussed (Berland & Hammer, 2012; Simon et al., 2006). In our opinion, this tendency can help students to avoid dialogue conflicts. Students seem to know that the argumentation would be more propitious to their position if they lead the argumentation to the topic that is advantageous to them. However, the topic-changing tendency does not benefit the production of high-quality arguments because it makes the argumentation fragmented. Students require guidance in order to stay focused on the point of a discussion. The guidance can be a request that scientific evidence be used as a backing, or a question seeking fuller explanations of their statements (Lin, Hong, & Lawrenz, 2012; Noroozi et al., 2012; Osborne, 2010). To improve the quality of student argumentation, a teacher should pay attention to the topic being discussed, when a topic of discussion was changed, and how it was changed, before giving guidance.

Exploring dialogue argumentation with a GR

The main feature of a GR is its bi-dimensional structure. This idea came from a study conducted by Sadler et al. (1997), and it provided us with a systemic way to code and explore the student argumentation data. In the structure of a GR, the x-axis represents time and the y-axis represents the type of discourse. For the former, it takes the question of 'when' into consideration, indicating what type of discourse was being proposed at what moment, when it was completed, and how long it took. For the latter, it allows researchers to analyze the dialogue argumentation by just focusing on a few types of arguments. This analysis helps to reveal the process of how a high (or low) level of discourse was constructed. A number of studies on the topic of scientific argumentation concern peers' dialogue interactions (Mercer, 2000; Walton, 1998) and guidance from teachers (Baker et al., 2012; Berland & Hammer, 2012; Lin et al., 2012; Osborne, 2010). To deal with these qualitative data, it may be necessary for researchers to develop instruments for systemic analysis. Thus, we considered the GR instrument for its potential utility in analyzing the students' dialogue interactions. However, it has not yet been widely employed in science education-related research, especially in exploring how students communicate their understandings of scientific concepts, science inquiries, and the nature of science. The application of GR still had its limitations in our data analysis. First, the development of the coding framework for the GR was difficult because the students' statements of their arguments were sometimes long and complex. The purposes of students' arguments were also unclear at times. For example, it is sometimes hard to distinguish personal rebuttals from those that are not personal in nature. In Episode 1, Daisy suggested to her opponents the possibility of shutting down a water treatment plant. Daisy's rebuttal had double meanings; it can be explained as a kind of taunt, or just a simple suggestion. In our analysis, it was difficult to tell if it was a personal or nonpersonal rebuttal. Moreover, a number of student statements proposed in debate activities cannot be categorized by the theory of TAP (Toulmin, 1958), such as stating a question, making a suggestion, giving a hint, or giving encouragement. In our opinion, such statements can be seen as elements for making TAP more applicable in argumentation teaching.

The pattern of the GR helped us to clarify the features of the student argumentation and to recognize the differences between the two topics and the two teachers. One obvious difference between the two teachers' instructional approaches in the first five minutes was the appearance of low-quality rebuttals (see Appendices 1 and 2). We found that the students in Linda's classroom generated more low-quality rebuttals than the students in Jack's classroom. This caused Linda to use the strategy of 'teacher management' to reconcile the students' personal rebuttals. Moreover, most of the symbols used for the GR of Jack's instruction were circular, indicating that the students were used to generating assertions and backings rather than rebuttals. These features helped us to explain the fact that there were more dialogue interactions between the two positions in the debate in Linda's classroom. That is, the students tended to respond immediately when they were rebutted by their peers on the negative team (Albe, 2008). The rebuttal arguments may have caused the use of the closed symbols in the GR. To improve students' production of evidence-based arguments, a teacher should be aware of what types of rebuttals are being proposed, try to reconcile any rebuttals that rely on personal attacks, and provide students with more time to construct arguments based on scientific theories and evidence. These indications correspond to the suggestion that the teaching of argumentation should be more reflective, interactive, and positive (Ferretti et al., 2000; Keefer et al., 2000; Nussbaum, 2005).

Conclusions

Dialogue conflicts during student argumentation influence the learning of argumentation skills and production of well-founded arguments. It is necessary for science teachers to reconcile students' emotional rebuttals (i.e. personal attacks) and guide the argumentation to be more based on rational and scientific evidence. The present study investigated the process of how dialogue conflicts are caused and how they can be reconciled in argumentation teaching. Three types of reconciling strategies were identified through the GR and qualitative analysis for science teachers to deal with students' challenges, counterclaims, and rebuttals during SSI debate activities. The first type of strategy consisted of reconciling via teacher management. This strategy can be applied when students' argumentation is flooded with emotional rebuttals. Teachers can temporarily take away students' right to speak and explain how to generate evidence-based arguments, and also explain how rational arguments will help us to better understand the topic under discussion. The second type of strategy consists of using a qualifier to bridge two opposing assertions. In rational argumentation, a claim should be generated by considering where and when it can be applied. Using a qualifier helps students to know the effectiveness and limitations of their arguments. Teachers have to assist their students in clarifying under what conditions a claim will or will not hold true, and then reconcile any dialogue conflicts caused by rebuttals. The third type of strategy for reconciliation suggests that science teachers can extend students' classroom debates to other scientific activities. To achieve this goal, teachers should be conscious of what is still unclear or insufficient in the arguments proposed by students as backings or rebuttals, and should then encourage them to correct any insufficiencies by exploring related information at the library or on the Internet, or by conducting scientific experiments. The three reconciling strategies lead argumentation activities to be more focused on knowledge evaluation and justification, a process which is involved in both talking about and conducting science. It is worth noting that our data showed that students can co-construct scientific arguments through discussions within their group. However, this will not happen if the topic of discussion is changed frequently. Therefore, teachers have to be aware of the topic being discussed and then ask students to provide more scientific explanations, evidence, and reasons under the same topic. We expect that this issue can be further explored by future studies on scientific argumentation.

International Journal of Science Education 2016.38:130-155.

Disclosure statement

No potential conflict of interest was reported by the authors.

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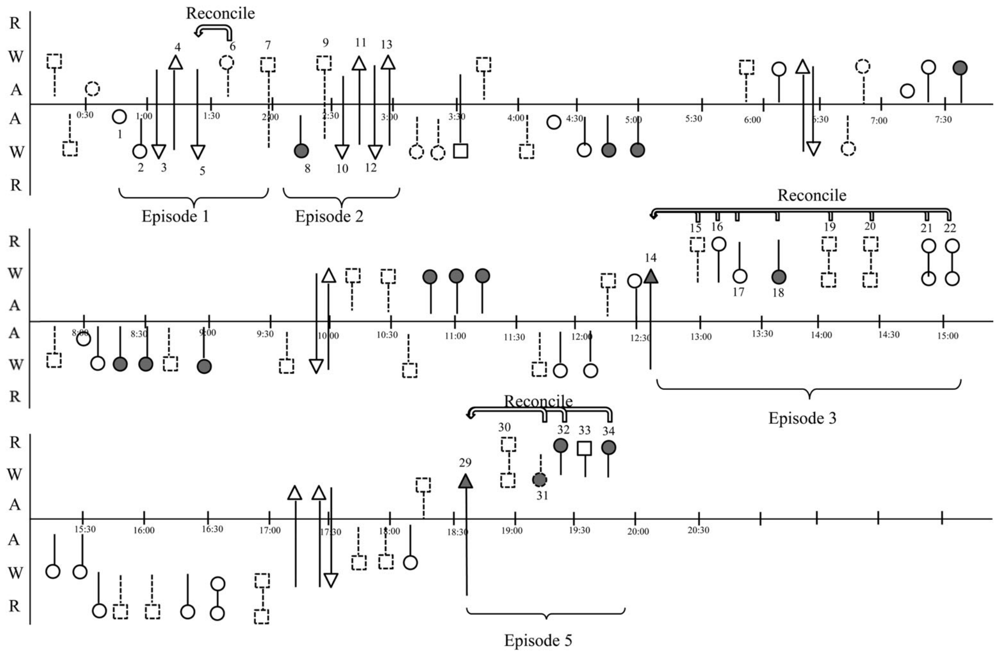
Appendix 1

GR of the surfactant activity.



Appendix 2

GR of the cosmetic activity.