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THE EFFECTS OF STUDENTS' STANDPOINTS IN ARGUMENTATION REGARDING SOCIO-SCIENTIFIC ISSUES

Yu-Ren Lin,
Tzu-Ting Wei

Abstract. *This study examined the effects of students' argumentation standpoints on their argumentation learning in the context of socio-scientific issues (SSIs). To that end, four kinds of argumentation standpoints were defined: affirmative standpoints, oppositional standpoints, multiple standpoints, and non-standpoints. These four kinds of standpoints allow for six possible combinations of any two of the different kinds of standpoints, which enabled us to conduct six kinds of 2-team format debates. The resulting differences of students' four types of arguments (i.e., claims, warrants, rebuttals, and qualifiers) generated in six types of debates were examined. This study invited 208 10th-grade students to participate in a quasi-experimental research design. The results showed the affirmative group students demonstrated superior performance in terms of claims and warrants, and the oppositional group students had the largest number of rebuttals. The students in the debate with combinations of affirmative and oppositional groups exhibited the best performance regarding the generation of claims, warrants, and rebuttals. Based on the results, the present study concluded the standpoint had significant effects on the students' argumentation learning, which suggests that teachers can investigate students' standpoint on the learning topic of SSI and their prior knowledge about the standpoint before teaching.*

Keywords: *argumentation learning, science education, socio-scientific issue, student standpoint.*

Yu-Ren Lin
National Tsing Hua University, Taiwan
Tzu-Ting Wei
Taoyuan Tzu Chiang Junior High School, Taiwan

Introduction

The use of socio-scientific issues (SSIs) in teaching science has been reported to be effective because such lessons provide learners with opportunities to engage in informal reasoning (Dawson & Venville, 2009; Zeidler et al., 2019), scientific explanation (Eggert et al., 2016; Gutierez, 2015), and argumentation (Cho & Jonassen, 2002; Grace & Ratcliffe, 2002). Ideally, the main goal for students in scientific argumentation activity is to engage in critical analyses of others' arguments. SSI debates constitute a typical form of scientific argumentation activity in which students are expected to assess the advantages and disadvantages of each position regarding the given issue (Zeidler et al., 2019; Ke et al., 2020). Previous researchers have reported that most middle school students are capable of articulating at least one perspective or standpoint/position in the context of an SSI activity (Lin, 2023; Anwar & Ali, 2020; Tekbiyik, 2015). Based on our own prior investigations, such student argumentation standpoints can be further categorized into four kinds of standpoints according to their stances in relation to the proposition under consideration: affirmative standpoints, oppositional standpoints, multiple standpoints, and non-standpoints. Taking the commonly discussed SSI "the nuclear power plant" as an example, a student who holds the affirmative standpoint would say "Yes, it would be no problem to construct a nuclear power plant in our country"; a student with an oppositional standpoint would argue that "no, building a nuclear power plant would be a bad decision"; and a student who holds multiple standpoints would consider a number of standpoints before making his or her argument. Such students may also say something like, "It depends; both decisions have their respective pros and cons, and so this issue requires further investigation". A student taking a non-standpoint usually has no clear preference regarding the SSI and may state that "both [the affirmative and oppositional standpoints] are acceptable" (or that "both are unacceptable").

Even though the mere expression of standpoints may not be a problem for most beginners or high school students, researchers have found that rigorous instructions and scaffoldings are still required in order to improve their argumentation abilities (Lin, 2023; Ekborg, 2008; Lee & Grace, 2010; Sadler, 2004; Zeidler et al., 2002). For example, Ratcliffe (1997) reported that it was rare for 15-year-old students to use scientific information in their reasoning and decision making during the discussion of SSIs. As she put it,

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"Scientific concepts may not appear as the most important factors in making decisions about socio-scientific issues (p. 179)". Walker and Zeidler (2007) developed a web-based inquiry-focused curricular unit to scaffold high school students' argumentation. They indicated that they still tend to back their assertions with personal opinions instead of evidence. Such a tendency "ultimately [leads] into numerous instances of fallacious reasoning and personal attacks (p. 1403)". To sum up, high school students may be lacking in argumentation and science content knowledge, and this lack of knowledge may cause them to rely exclusively on their personal opinions and only a limited amount of relevant information in arguing about SSIs (Lin, 2022; Hong & Chang, 2004; Klopp & Stark, 2022).To provide scaffolds for students' argumentation knowledge, a number of research used Toulmin's argumentation theory (Toulmin, 1958) as a fundamental data analysis foundation (Erduran et al., 2004; Weinberger et al., 2010). Toulmin explains that a sound argument will typically include six elements: data, claims, backings, warrants, rebuttals, and qualifiers (Toulmin, 1958). Researchers extended the Toulmin's theory and explained a number of aspects of knowledge and strategies required to construct a sound argument, including what counts as evidence, why counter-argument should be constructed, how to back a claim with scientific evidence, and so on (Erduran et al., 2004).

A number of studies have investigated how students' personal value and prior knowledge about the SSI influence their standpoints and decision making (Casas-Quiroga & Crujeiras-Pérez, 2020; Dauer et al., 2017; Herrenkohl & Guerra, 1998; Sadler, 2004). For example, Dauer and her colleague (2017) explored university students' reasoning process regarding SSIs. They explained that an individual's decision making was influenced by personal value orientations. However, in the SSI debate, the predictions from individuals' personal factors to decision making should be modified, or even reversed, because most of students have already made a stance before attending a debate. In our perspective, a standpoint a student made before debate would not only reflect his or her prior value, prior preference, and prior knowledge but would also affect the subsequent development of argumentation abilities. The current study explored how students' standpoints influence their science argumentation in the context of SSI. To that end, four kinds of argumentation standpoints were defined, which enabled us, in turn, to sort the participating students into four corresponding groups: the affirmative group (A group), the oppositional group (O group), the multiple-standpoint group (M group), and the non-standpoint group (N group). From the four groups, six distinct types of student debates can emerge. That is, debates between the A and O groups, debates between the A and M groups, debates between the A and N groups, debates between the O and M groups, debates between the O and N groups, and debates between the M and N groups. More specifically, by identifying the four kinds of standpoints and the six kinds of student debates, we can explore which type of student standpoint and which type of debate would benefit students' argumentation learning most. The research questions: (1) which kind of student argumentation standpoint regarding an SSI benefits students most in terms of the development and improvement of the four types of arguments (i.e., claims, warrants, rebuttals, and qualifiers) in the context of a within-group interview activity? (2) Which type of student debate yields the best argumentation and the most improvement in terms of the four types of arguments?

Research Methodology

Procedure

The current study utilized a quasi-experimental design. Before any argumentation instructions were presented to the participants, a number of SSIs were introduced to them in order to investigate their standpoints with respect to the SSIs. Two environmental SSIs, i.e., the "Su-Hua highway project" and "chemical cosmetics" SSIs, were then selected as they led to approximately equal distributions among the four kinds of standpoints. The experimental educational research on two SSI units lasted for eight weeks. Students were assigned to four groups based on their standpoints, and each group was further subdivided into three subgroups to engage in different argumentation activities; for example, students with A standpoint were divided into three subgroups participating in argumentation/debate activities with groups O, M, and N. To ensure that each subgroup had at least five students for better engagement in the activities, this study opted for a single experimental group design.

Before conducting the first experimental SSI activity, instructors spent two hours introducing the students to basic knowledge regarding argumentation, grouping them according to their standpoints on the SSI, explaining to them the basic strategies involved in collaborating with their peers to search for relevant information. The size of the student discussion group was five to six members. After the introductory lesson, all the students were given two to three hours to investigate related information on the internet, in the school library, and in

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their lab if necessary. They then participated in four 30- to 40-minutes long argumentation activities in order to learn about a given SSI. The first activity was a reflective judgment interview (RJI), which was conducted at the beginning of the autumn semester for the school teachers to choose scientific argumentation as the main topic for their professional development. The other follow-up three argumentation activities were two-team format debates in which a group of students with one kind of standpoint debated with, respectively, three groups of students with a different type of standpoint. The RJI is a semi-structured interview designed to elicit reliable data about an individual's (or individuals') fundamental beliefs about a particular concept/topic (King & Kitchener, 1994). Different from the RJI, the two-team format debates emphasized the dialogue argumentation between the different student groups. The teachers maintained a neutral stance when asking probe questions during the RJI and debate activities.

Participants

The participants of the study included two science teachers, as well as four classes comprising a total of 208 students who were in the 10th grade. Among these students, there were 198 female students and 10 male students. They were students from a regular high school located in the suburban area of central-southern Taiwan. The socioeconomic status of the community where the school is situated tends to be middle-class. The majority of students in the school specialize in nursing and biology. The school assigned all the students randomly to different classes. Thus, a relatively even distribution of students in terms of different abilities and levels of prior knowledge was assumed. The ANOVA results for the students' final science examination in the previous semester (pre-test) showed no significant differences in the levels of prior science knowledge among the A group ($N = 48$), O group ($N = 58$), M group ($N = 57$), and *N* group ($N = 45$) ($f = .021$, $p > .05$). The two teachers selected for participation in the present study were both Ph.D. candidates. They both majored in science education and had both obtained five years of experience in teaching science in the school.

The SSIs and Questions for Argumentation

The first SSI topic selected was the Su-Hua highway project SSI. The project was first proposed in 2011 and has since caused much discussion and argumentation among both the relevant governmental authorities and the citizens of this country. The probe questions about this SSI used by the two teachers in order to engage the students in argumentation were "Should we agree or disagree with efforts to undertake the Su-Hua highway project? What are your opinions and suggestions?" The second one concerned the use of cosmetics. The probe questions were "Do you believe that products of cosmetic are indispensable in a woman's daily life? Share your arguments and perspectives to substantiate your opinion".

Data Collection and Analysis

Quantitative analysis. One-factor repeated measure ANOVA and MANOVA analysis were used to explore the performance of students' argumentation during the two SSI activities, including their progressions and differences among the four groups in terms of using the four types of arguments.

Qualitative analysis. Based on the coding framework developed by previous studies (Erduran et al., 2004; Hogan & Maglienti, 2001), the Toulmin's theory was applied to develop an analytical framework for coding student arguments into types and categories. Each student argument generated during RJIs and debates was classified into one of the four types of arguments: claim, warrant, rebuttal, and qualifier. Furthermore, each student argument was classified into one of two levels of quality according to three principles: a) "Is the given argument rational, logical, and coherent?"; b) "Does the given argument state the source of authority and provide a relevant explanation?"; and c) "Is the given argument based on theoretical or empirical evidence?" If an argument met at least one of the three criteria above, it was deemed a level 2 argument. If an argument did not meet any of the three criteria, it was deemed a level 1 argument. In the quantity analysis, Level 1 arguments were assigned a code of 1, while Level 2 arguments were assigned a code of 2. All of the students' arguments generated during the RJIs and

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debates were videotaped and transcribed. The resulting transcripts were then read line-by-line by the first author and the two teachers. Any parts of the conversation that were not related to the task or topic were removed. Any inconsistencies were discussed further, and the cross-coder reliability was .89.

Analysis of students' dialogue argumentation. The strategies of content analysis were applied to explore qualitative data in order to ermine learning differences among the four standpoint groups, and, furthermore, to explain the results and findings of the quantitative analyses. We applied the coding framework constructed in our previous studies to analyze the students' performance in argumentation (Authors, 2022, 2023).

Research Results

Student Argumentation in Interview Activity

Figure 1 shows that all four groups of students produced more level 1 arguments during the second SSI interview than during the first one. A one-factor repeated measure ANOVA reveals that all four student groups had a significant improvement in their frequency of level 1 arguments in the second SSI interview (A group, $f_{(1)} = 28.91$, $p < .001$; O group, $f_{(1)} = 39.26$, $p < .001$; M group, $f_{(1)} = 30.55$, $p < .001$; N group, $f_{(1)} = 6.05$, $p < .05$). Among the four groups, the O group exhibited the largest improvement. A simple one-factor ANOVA was then conducted to examine the effects of the different kinds of standpoints on the four level 1 arguments. The results indicate that there was no significant difference among the four student groups during the first SSI interview. However, a different result was found in the analysis of the second SSI interview. The data not being homogenous ($f_{(1)} = 7.58$, $p < .01$), the *Welch* test was used, and it shows that the adjusted value was fine (*Welch* = 10.31, $p < .01$). The *Games-Howell* post hoc further shows that the N group students produced significantly fewer level 1 arguments than the A group students (*MD* = .89, $p < .01$), O (*MD* = .99, $p < .01$), and M (*MD* = .98, $p < .01$) groups.

Figure 1
Mean Frequencies of Level 1 Arguments Used by Students in Four Group Types During SSI Interviews

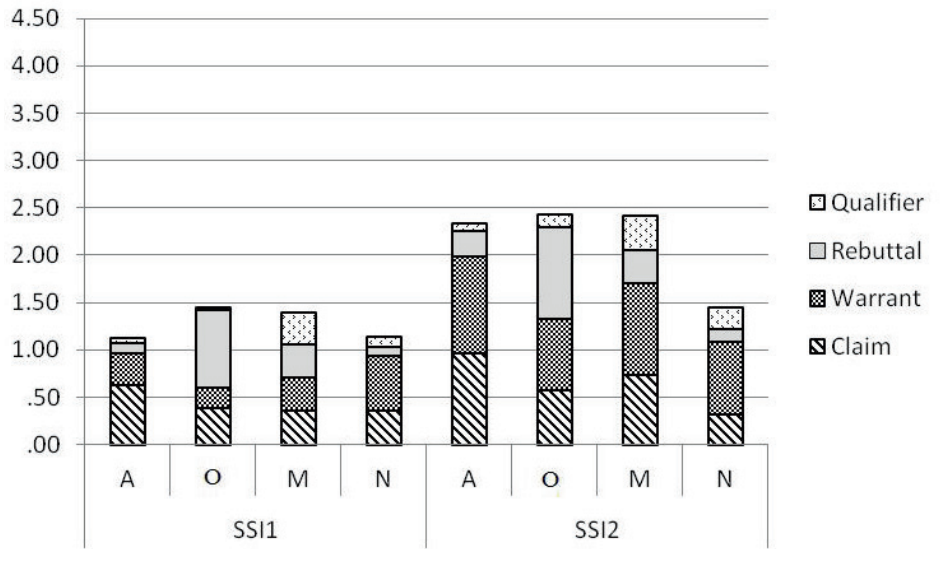

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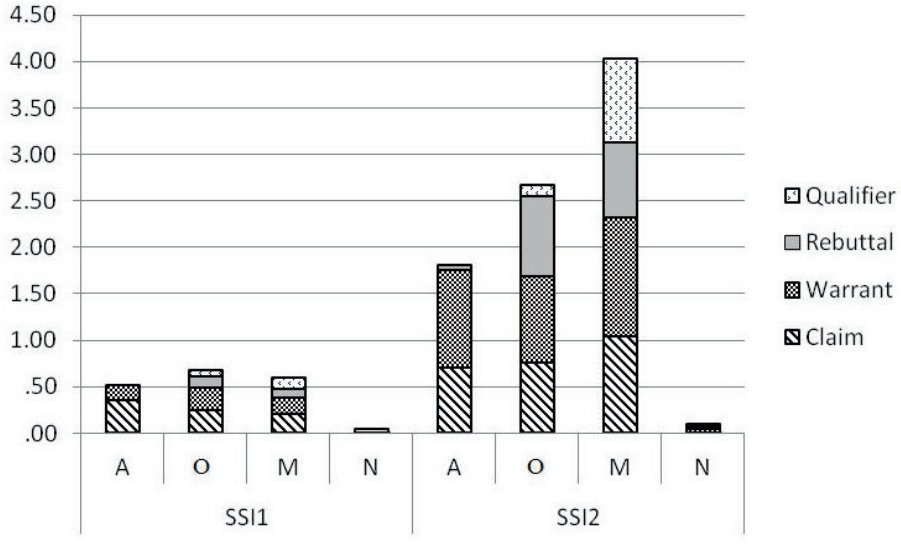
Figure 2
Mean Frequencies of Level 2 Arguments Used by Students in Four Group Types During SSI Interviews



The descriptive statistics regarding level 2 arguments show that all four student groups produced more of the four types of level 2 arguments in discussing the second SSI topic than in discussing the first one (Figure 2). A one-factor repeated measure ANOVA with the SSI topic as a repeated factor was therefore conducted to investigate the degree of their improvements. The results show that students in the A ($f_{(1)}$ = 39.24, p < .001), O ($f_{(1)}$ =118.07, p < .001), and M ($f_{(1)}$ = 150.94, p < .001) groups exhibited a significant improvement in the second SSI interview. Following that, a one-factor ANOVA was executed, with the standpoint serving as the independent variable and the frequency of Level 2 arguments as the dependent variable. The results indicate that the kind of standpoint had a statistically significant effect on the frequency of level 2 arguments produced in the first SSI interview. Since the homogeneity of variance of the data is invalid ($f_{(1)}$ = 30.61, p < .01). The result shows the adjusted value was fine (*Welch* = 13.35, p < .01). The *Games-Howell* post hoc shows that the A (*MD* = .52, p < .05), O (*MD* = .67, p < .01), and M (*MD* = .60, p < .01) groups performed significantly better than the N group. Importantly, the analysis of the second SSI interview indicated that the effect of the kind of standpoint became greater (*Welch* = 142.45, p < .001). A *Games-Howell* post hoc test furthermore shows that the M group performed better than the A (*MD* = 2.22, p < .001), O (*MD* = 1.36, p < .001), and N groups (*MD* = 4.01, p < .001); the O group performed better than the A (*MD* = .86, p < .05) and N (*MD* = 2.65, p < .001) groups; and the A group performed better than the N group (*MD* = 1.79, p < .001).

Table 1
One-Factor ANOVA of SSI Interviews

	n	SSI 1		SSI 2		SSI topics	
		M	SD	M	SD	F(p)	Simple main effect
Claim							
A group	48	1.33	1.41	2.37	1.64	11.23**	SSI2>SSI1**
O group	58	0.86	1.26	2.09	1.40	41.25***	SSI2>SSI1***
M group	57	0.77	1.15	2.81	1.70	95.84***	SSI2>SSI1***
N group	45	0.36	0.48	0.31	0.46	.281	
Warrant							
A group	48	0.67	1.03	3.10	1.58	65.12***	SSI2>SSI1***
O group	58	0.71	1.21	2.62	2.08	72.69***	SSI2>SSI1***

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	n	SSI 1		SSI 2		SSI topics	
		M	SD	M	SD	F(p)	Simple main effect
M group	57	0.70	1.13	3.53	1.88	114.58***	SSI2>SSI1***
N group	45	0.58	0.49	0.78	0.42	6.00*	SSI2>SSI1*
Rebuttal							
A group	48	0.11	0.31	0.40	0.73	6.87*	SSI2>SSI1*
O group	58	1.05	1.09	2.69	1.75	57.82***	SSI2>SSI1***
M group	57	0.53	0.88	1.96	1.84	53.25***	SSI2>SSI1***
N group	45	0.09	0.28	0.18	0.53	2.04	
Qualifier							
A group	48	0.06	0.24	0.08	0.27	1.00	
O group	58	0.17	0.65	0.38	0.95	6.01*	SSI2>SSI1*
M group	57	0.58	0.99	2.19	2.10	41.68**	SSI2>SSI1***
N group	45	0.11	0.31	0.22	0.42	2.89	

Note: ***p < .0001, **p < .001,*p < .01

The findings from Table 1 indicate that students in both the O and M groups demonstrated notable advancement in their ability to generate claims (the O group, $f_{(1)} = 41.25$, $p < .001$; the M group, $f_{(1)} = 91.84$, $p < .001$) and rebuttals (the O group, $f_{(1)} = 57.82$, $p < .001$; the M group, $f_{(1)} = 53.25$, $p < .001$). As for warrants, all four student groups exhibited a significant improvement during the second SSI interview (the A group, $f_{(1)} = 65.12$, $p < .001$; the O group, $f_{(1)} = 72.69$, $p < .001$; the M group, $f_{(1)} = 114.58$, $p < .001$; the N group, $f_{(1)} = 6.00$, $p < .05$). These results suggest that using claims and warrants in the SSI interviews did not seem to be a difficult task for most of the students. On the other hand, the results regarding the use of qualifiers were different, with the results indicating that the students rarely used this type of argument during the interviews. Such improvements indicate that the students gradually learned how to provide structure and level 2 arguments, although there were still level 1 arguments that were recorded. An example of the M group students' dialogue interactions in the RJI was provided to support our statistical findings. As for the A group, they had a significant improvement in their use of warrants, a slight improvement in their use of claims and rebuttals, and no significant improvement in their use of qualifiers. As for the N group, they exhibited no significant improvement with regard to any of the four types of arguments. We therefore concluded that, among the four student groups, the students in the O and M groups exhibited more improved performance in terms of their use of the four types of arguments.

Table 2
MANOVA Analysis of Four Arguments in the SSI Interviews

	Wilk's Λ	Multivariate F	Univariate F	Post Hoc Tests
Claim	.673	14.84***		
SSI1			5.67**	A >N group***
SSI2			28.43***	A >N group*** O >N group*** M >N group*** M >O group*
Warrant	.723	11.89***		
SSI1			.162	
SSI2			25.02***	A >N group*** O >N group*** M >N group*** M >O group*

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	Wilk's Λ	Multivariate F	Univariate F	Post Hoc Tests
Rebuttal	.613	18.76***		
SSI1			18.37***	O >A group*** O >M group** O >N group*** M >A group* M >N group*
SSI2			38.71***	O >A group*** O >M group* O >N group*** M >A group*** M >N group***
Qualifier	.658	15.77***		
SSI1			7.05***	M >A group*** M >O group** M >N group**
SSI2			35.18***	M >A group*** M >O group*** M >N group***

Note: ***p < .0001, **p < .001, *p < .01

The results of Table 2 indicate that this kind of standpoint factor had statistically significant effects on the use of claims (Λ = .673, $p < .001$), warrants (Λ = .723, $p < .001$), rebuttals (Λ = .613, $p < .001$), and qualifiers (Λ = .658, $p < .001$). A main effect analysis was therefore performed, and it indicates that, first, the kind of standpoint had a significant effect on the use of claims in both the first ($f_{(3)} = 5.67$, $p < .01$) and second ($f_{(3)} = 28.43$, $p < .001$) SSI interviews; *Sidak* test shows only the A group significantly outperformed the N group in first SSI interview (*MD* = .98, $p < .001$). The disparities among the four groups expanded further during the second SSI interview: the A group outperformed the N group (*MD* = 2.06, $p < .001$); the O group outperformed the N group (*MD* = 1.78, $p < .001$); and the M group outperformed the N group (*MD* = 2.50, $p < .001$) and the O group (*MD* = .72, $p < .05$).

Second, in terms of the use of warrants, the kind of standpoint had no statistically significant effect during the first SSI interview; however, it reached a statistically significant effect during the second interview ($f_{(3)} = 25.02$, $p < .001$). *Sidak* test further shows that the students in the A (*MD* = 2.33, $p < .001$), O (*MD* = 1.84, $p < .001$), and M (*MD* = 2.75, $p < .001$) groups had significantly better scores for their use of warrants than the N group. Moreover, the M group also exhibited significantly better warrant usage than the O group (*MD* = 2.75, $p < .001$). Third, in terms of the use of rebuttals, the type of standpoint also exhibited a statistically significant impact during both the first ($f_{(3)} = 18.37$, $p < .001$) and second ($f_{(3)} = 38.71$, $p < .001$) SSI interviews. The homogeneity of variance in the data is not valid for both the first ($f_{(3, 204)} = 36.68$, $p < .001$) and second ($f_{(3, 204)} = 26.11$, $p < .001$) SSI interviews. The result shows the adjusted value was fine for both the first (*Welch* = 121.11, $p < .001$) and second (*Welch* = 156.73, $p < .001$) SSI interviews.

The *Games-Howel* for the first SSI topic shows that the O group generated a better rebuttal score than the A group (*MD* = .95, $p < .001$), M (*MD* = .53, $p < .01$), and N (*MD* = .96, $p < .001$). The disparities among the four groups expanded during the second SSI interview; the O group students had significantly better rebuttal scores than their peers in the A (*MD* = 2.29, $p < .001$), M (*MD* = .72, $p < .05$), and N (*MD* = 2.51, $p < .001$) groups. As for qualifiers, the results indicate that the effect of the kind of standpoint reached statistical significance for both the first (*Welch* = 37.18, $p < .001$) and second SSI topics (*Welch* = 121.24, $p < .001$). *The games-Howell* test shows that the M group students had a better score in qualifiers than the A (*MD* = .52, $p < .001$), O (*MD* = .41, $p < .01$), and N (*MD* = .47, $p < .01$) groups in discussing the first SSI topic. For the second topic, the *Games-Howell* post hoc test results were similar to those for the first one. One difference, however, was that the mean difference and p-value for the second interview were higher, indicating that the M group students made greater progress than the A, O, and N group students in generating qualifiers.

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Student Argumentation in Debate Activity

A one-factor repeated measures ANOVA, with the SSI topic as the repeated factor, was performed to explore the extent of students' improvements in relation to the four Level 1 arguments. The descriptive statistics show, in general, the frequencies with which the four level 1 arguments in the six debates during the second SSI topic were higher than the frequencies with which they were generated during the first one (Figure 3). Moreover, the students who engaged in all six types of debates made significant progress during the second SSI debate with regard to their frequency of level 1 arguments (AO debate, $f_{(1)} = 7.56$, $p < .01$; AM debate, $f_{(1)} = 4.38$, $p < .05$; AN debate, $f_{(1)} = 68.06$, $p < .001$; OM debate, $f_{(1)} = 22.16$, $p < .001$; ON debate, $f_{(1)} = 55.01$, $p < .001$; MN debate, $f_{(1)} = 10.38$, $p < .01$). A one-factor ANOVA was conducted, and the independent variable was the debate type, while the four types of level 1 arguments served as the dependent variables. The results show the independent variable had a statistically significant effect on students' argumentation ($f_{(3)} = 3.09$, $p < .05$). *Sidak* test shows only the AO debate had better level 1 arguments than the AN debate significantly ($MD = 1.19$, $p < .05$).

Figure 4 shows that the frequencies of level 2 arguments generated by the students in the six debates during the second SSI topic were higher than that generated during the first one. Moreover, the AO and AM debates yielded the highest frequencies of level 2 arguments, while the AN and ON debates yielded the lowest frequencies of level 2 arguments among the six types of debates. A one-factor repeated measure ANOVA indicates that the students who participated in all six types of debates made significant progress regarding the level 2 arguments during the second SSI debate (the AO debates, $f_{(1)} = 78.67$, $p < .001$; the AM debates, $f_{(1)} = 100.34$, $p < .001$; the AN debates, $f_{(1)} = 28.70$, $p < .001$; the OM debates, $f_{(1)} = 84.98$, $p < .001$; the ON debates, $f_{(1)} = 24.70$, $p < .001$; the MN debates, $f_{(1)} = 28.38$, $p < .001$).

Figure 3
Mean Frequencies of Level 1 Arguments Used by Students in Six Types of SSI Debates

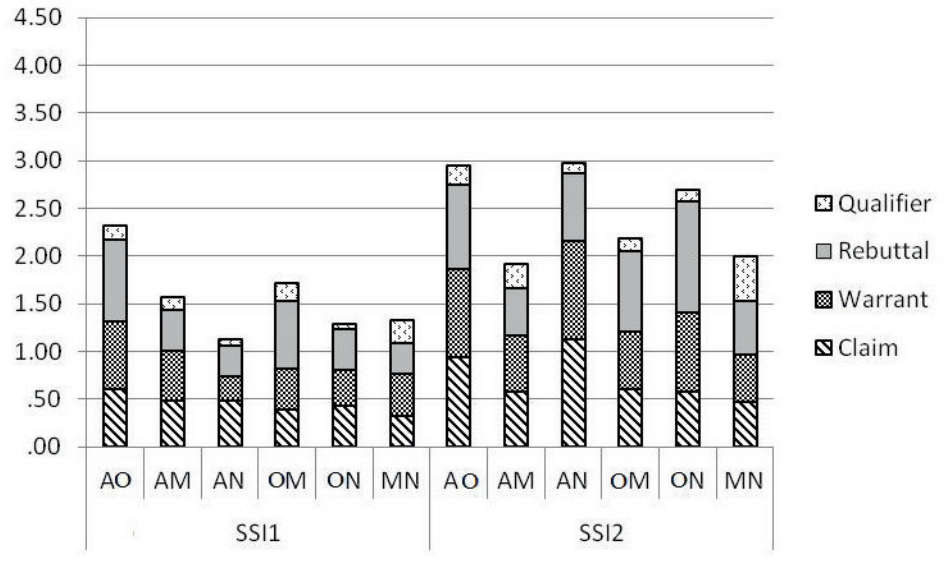

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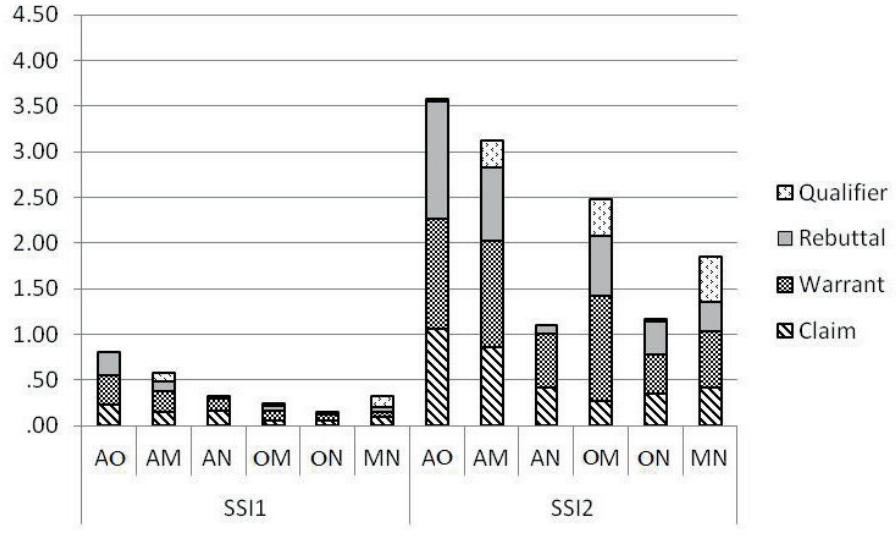
Figure 4
Mean Frequencies of Level 2 Arguments Used by Students in Six Types of SSI Debates



A one-factor ANOVA was then applied to investigate the effect of the type of combination on the frequency of level 2 arguments generated in the first and second SSI debates.

The results show that the homogeneity of variance of the data was invalid for the first SSI ($f_{(5, 202)} = 5.51, p < .01$) and second SSI ($f_{(5, 202)} = 5.83, p < .01$), so the *Welch* test was then used. The *Welch* test results show that the adjusted values were fine for both the first (*Welch* = 2.57, $p < .05$) and second (*Welch* = 17.29, $p < .01$) SSI debates. Follow-up *Games-Howell* post hoc for the second SSI debate shows that the AO debate students produced better level 2 arguments than the AN significantly (*MD* = 2.47, $p < .001$), ON (*MD* = 2.40, $p < .001$), and MN (*MD* = 1.72, $p < .001$) debate students. Moreover, the AM debate performed better than the AN (*MD* = 2.02, $p < .001$), ON (*MD* = 1.94, $p < .001$), and MN (*MD* = 1.26, $p < .05$) debate; the OM debate performed better than the AN (*MD* = 1.38, $p < .01$), and ON (*MD* = 1.30, $p < .05$) debate. Such results implied to us that the students in the AO, AM, and OM debates could produce more level 2 arguments during the second debate activity.

The results in Table 3 indicate that the students participating in all six types of debates had significant improvement in terms of their scores for arguments such as rebuttals, warrants, and claims during the second SSI debate. It is worth noting that only three groups (the AM, OM, and MN debate students) made significant progress in their use of qualifier arguments. Among those three groups, we found that the MN debate students improved the most.

Table 3
One-Factor ANOVA Analysis of Debate Activity.

	n	SSI 1		SSI 2		SSI topics	
		M	*SD*	*M*	*SD*	*F(p)*	Simple main effect
Claim							
AO group	35	1.06	1.16	3.06	2.07	37.18***	SSI2>SSI1***
AM group	35	0.77	1.14	2.29	0.86	66.97***	SSI2>SSI1***
AN group	31	0.81	1.08	1.97	1.47	47.88***	SSI2>SSI1***
OM group	38	0.50	0.76	1.13	1.17	13.09**	SSI2>SSI1**
ON group	35	0.54	0.78	1.26	1.34	12.35**	SSI2>SSI1**
MN group	34	0.50	0.83	1.29	1.34	19.89***	SSI2>SSI1***
Warrant							
AO group	35	1.34	1.16	3.31	1.89	32.39***	SSI2>SSI1***
AM group	35	0.97	1.15	2.94	1.68	60.08***	SSI2>SSI1***
AN group	31	0.52	1.03	2.19	1.33	75.25***	SSI2>SSI1***

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	n	SSI 1		SSI 2		SSI topics	
		M	*SD*	*M*	*SD*	*F(p)*	Simple main effect
OM group	38	0.63	0.94	2.92	2.17	47.91***	SSI2>SSI1***
ON group	35	0.49	0.78	1.69	1.57	33.20***	SSI2>SSI1***
MN group	34	0.56	0.79	1.74	1.66	20.72***	SSI2>SSI1***
Rebuttal							
AO group	35	1.37	1.00	3.46	1.69	53.51***	SSI2>SSI1***
AM group	35	0.66	0.91	2.09	1.63	29.41***	SSI2>SSI1***
AN group	31	0.39	0.67	0.90	1.25	11.39*	SSI2>SSI1*
OM group	38	0.82	0.69	2.16	1.82	24.69***	SSI2>SSI1***
ON group	35	0.49	0.66	1.91	1.58	41.46***	SSI2>SSI1***
MN group	34	0.44	0.70	1.21	1.17	27.20***	SSI2>SSI1***
Qualifier							
AO group	35	0.14	0.36	0.26	0.61	2.80	
AM group	35	0.31	0.80	0.83	1.10	5.75*	SSI2>SSI1*
AN group	31	0.06	0.25	0.10	0.30	1.01	
OM group	38	0.24	0.59	0.92	1.40	12.60**	SSI2>SSI1**
ON group	35	0.06	0.24	0.17	0.57	2.80	
MN group	34	0.47	0.93	1.47	1.73	21.57***	SSI2>SSI1***

Note: ***p<.0001, **p<.001, *p<.01

Table 4 presents that in general, the variables had statistically significant effects on the use of claims (Λ = .799, p < .001), warrants (Λ = .837, p < .001), rebuttals (Λ = .745, p < .001), and qualifiers (Λ = .823, p < .001). A main effect analysis was therefore performed, and the results indicate that the type of combination affected the use of claims significantly only during the second ($f_{(5)}$ = 9.98, p < .001) SSI debate. A *Sidak* post hoc test further reveals that the students in AO debates had better scores in terms of claims than the students who engaged in AN (*MD* = 1.09, p < .05), OM (*MD* = 1.93, p < .001), ON (*MD* = 1.80, p < .001), and MN (*MD* = 1.76, p < .001) debates. Moreover, it was also found that the students in the AM debates had better claim scores than the OM (*MD* = 1.15, p < .01), and ON (*MD* = 1.03, p < .05) debates.

Table 4
MANOVA Analysis of Four Arguments in the Two SSIs Debate Activities

	Wilk's Λ	Multivariate F	Univariate F	Post Hoc Tests
Claim	.799	4.77***		
SSI1			1.86	
SSI2			9.98***	AO >AN group * AO >OM group *** AO > ON group *** AO >MN group *** AM >OM group ** AM > ON group *
Warrant	.837	3.73***		
SSI1			4.09**	AO >AN group * AO >OM group * AO > ON group ** AO >MN group *
SSI2			5.39***	AO > ON group ** AO >MN group ** AM >OM group *

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Rebuttal	.745	6.37***		
SSI1			7.56***	AO >AM group ** AO >AN group *** AO >OM group * AO > ON group *** AO >MN group ***
SSI2			11.14***	AO >AM group ** AO >AN group *** AO >OM group ** AO > ON group ** AO >MN group *** OM >AN group * AM >AN group *
Qualifier	.823	4.10***		
SSI1			2.47*	
SSI2			8.40***	MN >AO group *** MN >AN group *** MN > ON group *** OM >AN group *

Note: ***p<.0001, **p<.001, *p<.01

As to warrant arguments, the type of combination had significant effects for both the first ($f_{(5)} = 4.09$, $p < .01$) and second ($f_{(5)} = 5.39$, $p < .001$) debate activities. A *Sidak* post hoc test shows that the students in the AO group had a significantly better warrant score than the students in the AN (*MD* = .83, $p < .05$), OM (*MD* = .71, $p < .05$), ON (*MD* = .86, $p < .01$), and MN (*MD* = .78, $p < .05$) debates for the first SSI debate. For the second SSI debate, the AO debate students still had better warrants than their peers in the ON (*MD* = 1.63, $p < .01$), and MN (*MD* = 1.58, $p < .01$) debates. For rebuttal arguments, the differences among the six types of debates are also statistically significant in both the first ($f_{(5)} = 7.56$, $p < .001$) and second ($f_{(5)} = 11.14$, $p < .001$) SSI debates. *Sidak* shows that the AO debates had a better score in terms of their use of rebuttals than the students in the other five debates for both the first and second SSI debates. As for the use of qualifiers, the type of combination had significant effects during both the first ($f_{(1)} = 2.47$, $p < .05$) and second ($f_{(1)} = 7.56$, $p < .001$) SSI debates. Although the homogeneity of variance of the data was invalid for the first SSI ($f_{(5, 202)} = 10.08$, $p < .001$) and second SSI ($f_{(5, 202)} = 28.31$, $p < .001$), the results of the *Welch* tests show the adjusted value was fine for both first (*Welch* = 2.38, $p < .05$) and second (*Welch* = 90.90, $p < .001$) SSI debates.

The Follow-up *Games-Howell* post hoc test indicates that there was no statistically significant difference among the six groups in the first SSI debate. However, for the second SSI, the MN debate performed better than their peers in the AO (*MD* = 1.21, $p < .001$), AN (*MD* = 1.37, $p < .001$), and ON (*MD* = 1.30, $p < .001$) debates. Moreover, the OM debate had slightly better qualifiers than the AN debate students (*MD* = .82, $p < .05$). The analysis indicates that using qualifiers during the debate activities seemed to be a difficult task for most of the students, except for the students who engaged in the MN and OM debates.

The Students' Argumentation in the RJIs and Debates

As to the student argumentation in the RJI. We focused on the groups and individual students whose performance scores were near the mean in order to explore the features of their argumentation. Follow-up response is an example of an M group student's (July) arguments in a cosmetic SSI interview. July shared her reasons for using and not using chemical cosmetics.

There is different scientific evidence for supporting to use and not to use (chemical cosmetics). For example, people who agree with using cosmetics may say that it enhances our confidence. However, it actually can't enhance our inner confidence. Here is an article I found on the internet in a research journal of 2002. The author, Rich, said that "upper-social women, especially adolescents and young adults, are the most dissatisfied with their bodies. They may use cosmetics to hide the things they do not like. However, their inner confidence is hardly to be increased."

As an M group student, she holds multiple points of view about the issue in both the first and second top-

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ics of SSI. However, an improvement of her argumentation during the second topic of SSI was that she quoted statements from a research study to back her stance. Her arguments were sound and clear not only because the author and publishing year of the study were mentioned but also because the specific participants of the study were highlighted (upper-social adolescents, especially adolescents and young adults). In the analysis of the July's argument, we found that, first, she understood that to quote scientific information as backing would make her statement persuasive. Second, she knew how to quote scientific information as backing. Third, she also understood the authors' statements were limited primarily to these "upper-social women". Based on the analytical framework, the statement was regarded as a level 2 qualifier argument.

The following qualitative example shows the students' argumentation in the OA debate.

1. Tina: *cosmetics is one of the important factors to improve our economic growth. For example, in China's and Turkey's cosmetics market, cosmetic companies are continuing to expand rapidly.*
2. Abby: *You are right; I have related information about Turkey's case; it is reported that the value of the beauty and personal care market in Turkish grew by 15.4%, about 3 billion in 2012.*
3. Lee: *Maybe you are right, but I still believe that the most important aspect when making decisions about cosmetic issues would be the consideration of our environment.*
4. Susan: *Yes, I agree with her (Lee). Here, I listed a number of environmentally damaging chemicals that are generally used in cosmetic products, such as synthetic fragrances, talc, and preservatives like butylparaben. The chemicals are recycled into our lakes, rivers and even into our food-chain systems.*

Tina, a student in the A group, stated that cosmetic products and companies play an important role for a country's economic growth (No.1). A team member of Tina, called Abby, quoted a statement from a newspaper to support Tina's argument (No.2). After that, an O group student (Lee) provided a disagreement (No.3). He respected the scientific information embedded in Abby's statement. However, he indicated that our environmental protection should be the first concern for making decisions regarding the cosmetic issue. Susan, a team member of Lee, agreed with Lee's point of view and pointed out a number of damaging chemical ingredients used in most of cosmetics (No.4). The episode shows that students gradually learned to support their assertions by using scientific information and evidence. One reason for explaining the improvement would be that they believe the use of scientific information would increase the persuasion of their statements. On the other hand, embedding scientific information in arguments could also be an effective strategy to make a response equal to these evidence-based arguments.

As to the MN debate. They appeared to be productive in using qualifiers. The reason was that the M group students tried to point out and explain the pros and cons of SSI and expected their opponents (the N group students) to be more serious in discussing the cosmetic issue.

5. Lee: *To use or not to use cosmetics is a personal affair.*
6. Helen: *Yes, but if you don't know how to use cosmetics, they will damage your skin.*
7. Sandy: *there are several chemical ingredients that have been reported harmful to our skin, such as formaldehyde, hydroquinone, and mercury. You should read the ingredient labels on cosmetic products.*
8. Vivian: *If you have to use them, please choose brands that adhere to independent certifications. If the products were organic and only made with natural materials, we could use them. I share my favorite organic makeup brands to give your skin a healthy glow…*

At the beginning of the debate, the N team students had few comments about the cosmetic issue because they regarded it as a personal business (No. 5). Different from the N group students, the M group students (Helen, Sandy, and Vivian) used scientific information collected from newspapers and reports to persuade the N group students to be concerned about the issue seriously. They explained how to choose and use cosmetics, which is important to our skin health. Sandy indicated a number of chemical ingredients which are reported harmful to our skin (No. 7). Vivian provided a strategy to tell a cosmetic which was made with organic materials from these was not (No. 8). Sandy's and Vivian's statements both are rational, and involved reasons of using and not using cosmetics, and thus, they were coded as a level 2 qualifier respectively in our analyses. They proposed level 2 qualifiers and tried to inform the N team students to select good cosmetic products before using them.

Discussion

The data from the debate reveals that the O group was more competitive in nature. In addition, most of the rebuttals produced by the O group were level 1 rebuttals, especially in the first SSI interview. This implies that these rebuttals tended not to be based on scientific evidence or theory. Mercer (2000) used the term 'disputational

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talk' to explain students' challenges and exchanges of rebuttals in argumentation. According to researchers, it has been found that the majority of middle school students possess the capability to offer rebuttals primarily based on personal opinions; however, rebuttals based solely on personal opinions do not contribute to students' learning of argumentation, importantly, may cause conflicts and thus harm the classroom atmosphere (Albe, 2008; Lin, 2023; Zohar & Nemet, 2002; Zhu et al., 2020). This was an explanation of why level 2 arguments were rarely coded for the first interview of the O group. However, we considered that this tendency toward disputational talk should be seen as part of the process of students' learning because our data also showed that the O group students made a significant improvement in terms of their scores for rebuttals and claims during the second SSI interview.

It is worth noting that the M group demonstrated the highest overall argumentation performance among the four student groups, excelling in both the quality and quantity of the four types of arguments. These results can be explained by Kuhn's theory of the development of people's epistemological understanding (Casas-Quiroga & Crujeiras-Pérez, 2020; Klopp & Stark, 2022; Kuhn et al., 2000). Among the four groups, the results showed that the N group students exhibited the least improvement and the least ability overall in their argumentation. Although the N group students did not perform well in their argumentation, their score in terms of the warrants they generated was found to be as good as the scores of the other three groups. This implied to us that a teacher could guide the N group students to construct various arguments, i.e., claims, backings, rebuttals, and qualifiers, based on the knowledge and ways they construct warrants in order to create successful argumentation experiences for them.

According to previous studies, the use of qualifier arguments poses a difficult task for most students because such usage emphasizes students' reflections and evaluations of multiple standpoints on the given issue (Author, 2022; Means & Voss, 1996; Schwarz et al., 2003). This kind of knowledge evaluation is, therefore, likely to take place in a debate with more exploratory talk rather than disputation or persuasion-related talk (Albe, 2008; Lin, 2023; Nussbaum, 2005; Osborne, 2005; Zhu et al., 2020). Based on this, the N group would combine more smoothly with the M group because their standpoint about the SSI was not as strong as those of the A and O groups, thus making the goal of the MN debate less about contradictory confrontations in which one student attempts to persuade others to accept his or her view and disagrees with any alternative objections, questions, or alternative claims. With less of a goal of persuading, the MN group students would have more chances to share their ideas, construct knowledge claims, and be curious about others' ideas. This kind of learning atmosphere would provide opportunities for students to construct arguments from multiple points of view and, therefore, support the development of qualifier arguments.

Conclusions and Implications

An important result in the present study was that both the two factors: argumentation standpoint, and the combinations of two different argumentation standpoints for debate had significant effects on the frequency, as well as the quality of students' using the four types of arguments, namely, claims, warrants, rebuttals, and qualifiers in the SSI activities. Such effects increased in discussing the second SSI topic, indicating the more experience and knowledge regarding scientific argumentation students have, the greater the effect of their standpoint on their argumentation performance. The present study utilized two forms of argumentation in order to deepen our explorations of these issues in the SSI context: interviews and debates. The former form of activity emphasized the students' within-group discussions and negotiations. We found that the A group students had the best performance in terms of producing claims and warrants among the four groups. Moreover, they produced fewer and weaker rebuttal arguments in both the RJI and debate activities. In contrast with the A group, most of the arguments generated by the O group were rebuttals and warrants.

The statistical results indicate that all six types of student debates exhibited significant improvements in the utilization of claims, warrants, and rebuttals, whereas only half of the debate students, i.e., the students in the MN, MA, and MO debates, acquired significant improvements in term of using qualifiers. One obvious feature among those three combinations is the involvement of the M group students. As we discussed above, the M group students were the ones who exhibited the best ability in constructing qualifiers among the four groups because of their multiple perspectives on the issues. This could be a reason explaining their significant improvements. What makes us curious is why the MN group had the best improvement while the AM and OM groups had less significant improvement in terms of the use of qualifiers.

These results suggest that teachers can investigate students' standpoint on the learning topic of SSI and their prior knowledge about the standpoint before teaching. We also believe that students' standpoints are not limited to the four types distinguished in this study, and such expectations can be further explored in future research.

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Declaration of Interest

The authors declare no competing interest.

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Yu-Ren Lin PhD, Assistant Professor, Graduate Institute of Mathematics and Science Education, National Tsing Hua University, 300193 No.521, Nanda Rd. Hsinchu City, Taiwan, R.O.C.
E-mail: linyuren@mx.nthu.edu.tw
Website: https://gimse.site.nthu.edu.tw/p/404-1115-221458.php?Lang=zh-tw
ORCID: https://orcid.org/0000-0003-0658-4695

Tzu-Ting Wei MSc, Taoyuan Tzu Chiang Junior High School, No.80, Rongmin Road, Chungli District, Taoyuan City, Taiwan (R.O.C.).
E-mail: ting74821@yahoo.com.tw