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The Effects of Argument Stance on Scientific Knowledge Inquiry Skills

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This study investigates the effects of argument stance on knowledge inquiry skills. Sixty-two participants were assigned to three argument stance conditions (proponent, opponent, or control) to receive scaffolded argumentation practice on two science issues in random order. After the argumentation treatment, participants were asked to write down their own opinions regarding the claim. Their responses were analysed according to argument structure, argument content, methods of refutation, and number of new propositions. Results revealed that taking a proponent's stance increased the use of evidence in argumentation, while taking an opponent's stance enhanced both the use of evidence and alternative-based refutations to the claim, number of falsifications, and number of new propositions. This implies that arguing from an opponent's stance may increase the search for multiple causes behind observed phenomena and the need for evidence, thereby alleviating the confirmation bias in thinking.

Keywords: *Argumentation; Argument stance; Scientific inquiry skills; Science text*

Argumentation is considered a rational and deliberate method for knowledge inquiry in Western history (Bricker & Bell, 2008; van Eemerren & Grootendorst, 2004; Johnson, 2000; Toulmin, 1958/2003). It involves claiming one's position regarding a controversial issue openly, providing explanations and evidence to support one's claim, and inviting counterarguments with the goal of scrutinising one's belief critically (Bricker & Bell, 2008; Kuhn, 1991; Toulmin, 1958/2003). As a result, revision or conceptual change can be done to the existing knowledge. Argumentation

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highlights the necessity of the congruence between theory and evidence in knowledge construction and justification. Only those ideas that remain unchallenged after vigorous argumentation can be temporarily regarded as valid knowledge (Kuhn, 2001; Meiland, 1989; Siegel, 1995). Scientists and engineers are always required to convince their peers and others of the value and validity of their ideas and findings (Bricker & Bell, 2008; Sismondo, 2004). Thus, in science education, one of the skills essential for students to master as a foundation for skilled scientific thinking, aside from skills in designing and conducting controlled scientific studies, is the ability to engage in skilled argumentation in the scientific domain (Erduran & Jimenez-Aleixandre, 2008; Erduran, Simon, & Osborne, 2004; Kuhn, 2010; Kuhn, Iordanou, Pease, & Wirkala, 2008; Kuhn & Pease, 2008; Kuhn, & Undell, 2007).

However, argumentation practice is beneficial to knowledge inquiry only if the parties involved in argumentation are unbiased and the pros and cons of the issue are presented fairly and thoroughly. Therefore, designing an argumentation procedure that gives different views a fair chance is of prime importance to the effectiveness of argumentation as a means of knowledge inquiry. Argumentation can occur individually or between two parties holding opposing views on the issue. The purpose of this study was to examine the effect of argument stance (proponent *vs*. opponent) on scientific knowledge inquiry skills when argumentation was practised by an individual. By knowledge inquiry skills, we refer to the cognitive abilities to examine critically (to confirm or disconfirm) the validity of an assertion to bring about changes or revisions to the existing belief or knowledge. We predicted that taking the opponent stance in argumentation practice would promote scientific knowledge inquiry skills more than taking the proponent stance.

Argument Structure and Myside Bias in Reasoning

For argumentation to be regarded as a method of knowledge inquiry, some minimal structural requirements must be met (Angell, 1964; Rybacki & Rybacki, 1996; Toulmin, 1958/2003):

(1) *Claim*: one must take a stance regarding what one believes regarding the issue at debate.
(2) *Evidence*: a claim regarding something is merely a person's belief. A belief cannot be qualified as valid knowledge unless it is grounded in fact, that is, matters we can observe directly or indirectly in reality (Kuhn, 1991). Empirical evidence may appear in two forms: an exemplar/case that can be perceived by our senses or statistics that are aggregated from data (Limon & Kazoleas, 2005). However, empirical evidence is difficult and expensive to obtain and is easily contaminated. Moreover, evidence is just raw data. Its meaning needs to be interpreted. Therefore, evidence must be augmented through explanation.
(3) *Explanation*: the relation between evidence and a claim must be explained. Unless there is a reasonable relation between the evidence and claim, evidence provides no support for the claim. Theoretical coherence and evidential coherence are keys

to checking the validity of explanations (Kuhn & Pearsall, 2000). Namely, all the evidence must point to the same conclusion, and this evidence must be explained by existing theories.

(4) *Counterargument*: according to Popper (1968), supporting evidence cannot prove a rule, but a single piece of evidence that is counter to the rule can falsify the rule decisively. Therefore, for a claim to be accepted as valid, the existence of any negative evidence or alternative explanations must be critically examined.

(5) *Rebuttal*: to retain one's claim, the proponent must refute an opponent's counterarguments by citing evidence or explanations that are incongruent to the counterarguments.

Argumentation practice can be performed by an individual, between individuals, or among groups. To impose an argument structure on argumentation practice is to ensure that different opinions have an equal chance to be evaluated. Humans are notoriously biased. Confirmation bias is a robust phenomenon in that people attend only to data that is consistent with their prior beliefs and are blind to data inconsistent with their beliefs (Evans, 1989; Wason & Johnson-Laird, 1972). Extensive laboratory studies have shown that this tendency poses a significant threat to belief revision and knowledge updating because ideas or data inconsistent with one's belief or current goals would be screened out unconsciously (Most, Cliford, & Simon, 2005). Therefore, finding an opponent, inviting counterarguments, and responding to criticisms are necessary steps in the knowledge validation procedure.

For example, in an experiment with 54 college students, Baron (1995) manipulated the claim to be consistent or inconsistent with participant's belief. The results showed that participants preferred arguments that were consistent with their beliefs, and Baron referred to this phenomenon as 'myside bias'. Moreover, data also indicated that participants preferred arguments that were one-sided rather than those that were more balanced in terms of enumerating pros and cons towards the claim, which was termed 'one-side bias'.

In addition, Kuhn (1989) examined participants' ability to raise alternative accounts for data. She found that approximately 36% of the participants could not raise any alternative account of phenomena. The reason behind the failure was that participants tended to erroneously regard alternative accounts as inherently embedded in their initial claim (50%), or they believed that their claim was sufficient to account for all. Kuhn's data also indicated that people would refute an alternative account more readily if the account was different from their beliefs as compared to if it was congruent with their beliefs.

Therefore, inviting refutation is a critical but difficult task in knowledge inquiry. The function of refutation is to examine the validity of the knowledge structure used to support the causal inferences of the claim. The approaches that people use to refute an idea can be classified into three types (Shaw, 1996):

(1) Assertion-based refutation; the premises and conclusions of an argument are examined to check for coherence with existing knowledge and to determine whether the explanations and evidence provided in the argumentation are valid.

(2) Argument-based refutation; the logic of reasoning is checked to see if there is any erroneous or inconclusive deduction in the argument.
(3) Alternative-based refutation; proposing an alternative account of the issue under debate is a way to weaken the necessity of a claim (Platt, 1964).

Thus, to refute an argument, one must possess relevant domain knowledge as well as the ability to analyse the logic of the arguments critically, such as distinguishing the premise of an argument from the conclusion of an argument. Shaw's (1996) study showed that failure to distinguish a premise from a conclusion might hinder one's ability to refute an argument. In the study, 20 college students were asked to refute the claim raised in a text. Half of them were asked to evaluate the credibility of the premises and the conclusions of the arguments prior to the refutation task. Shaw found that participants who had the opportunity to examine the credibility of the premises and conclusions raised significantly more refutations against the arguments in the text (approximately 33%) when compared to the control group (18%). Analysis of their refutations indicated that 54% of the refutations were assertion-based refutations, only 24% were argument-based refutations, and 22% were alternative-based refutations. It seems that it is more difficult for participants to raise argument-based and alternative-based refutations than it is to make assertion-based refutations, which could be due to the difficulty of logical analysis.

Taking the Opponent Stance in Argumentation

Argumentation is a common practice among scientists (Kuhn & Pearsall, 2000). Therefore, practising argumentation is an important method for promoting and cultivating students' scientific inquiry skills (Erduran & Jimenez-Aleixandre, 2008; Kuhn, 2010). Argumentation practice can involve two parties holding opposing positions regarding an issue, or it requires an individual to argue both the pros and cons of an issue. Either way, one must consider the opponent's view in order to facilitate the falsification of one's own position in knowledge inquiry. Therefore, designing an argumentation practice to accomplish this goal more effectively is a valuable endeavour. The present study examined the role of an argument stance in individual argumentation practice on promoting falsification behaviours.

Primacy effect is a robust phenomenon in human cognition (Asch, 1946; Crano, 1977; Forgas, 2011). It refers to people's tendency to be influenced by information in the order it comes to their attention. Early information was found to have a disproportionate influence on people's memory and judgements such as the effect of the first impression in social judgement. Primacy effects occur because people often pay more attention to early information and fail to process later information as carefully and attentively as earlier information due to short-term memory constraints (Crano, 1977). The item that appears at the beginning of a sequence has a more profound effect on people's memory, and thus subsequent behaviours, than those that appear later. Therefore, this study predicted that when practising argumentation alone, those who assume the proponent's role will tend to focus their attention on supporting

explanations and evidence for the claim and consequently pay less attention to the reasons and evidence that are inconsistent with the claim. In contrast, those who assume the opponent's role in argumentation practice will process the negative evidence and inconsistent reasons of the claim more thoroughly, which could possibly lead to more knowledge inquiry and falsification behaviours.

Method

Participants

Nineteen undergraduate and 50 graduate students (40 males and 29 females) from a university in Taiwan participated in the current study. Most of them participated to fulfil course requirements. They were randomly assigned to one of three argument stance conditions (proponent, $n = 22$; opponent, $n = 25$; control, $n = 22$). Seven participants were deleted from the sample for one of the following reasons: (1) the content of their post-test argumentation was unrelated to the issue, (2) a claim was stated without any argument; (3) outliers in terms of the time spent on the post-test argumentation (>30 min); or (4) responses in arguments indicated a lack of understanding of the text.

Argumentation Tasks

Two science texts, one on the causes of depression and the other on the efficiency of an automated highway system, were taken from science reports and re-written so that each contained a claim made by a professor, explanations to support the claim, a study that provided supporting evidence, counterarguments from a colleague in the same field, and the rebuttals of the author of the claim (Lin, 2006). Each text was approximately 500 words (1 page), with the identity of the author and the claim highlighted on the top of the page. The claim made regarding the cause of the depression was 'depression is caused by an imbalance of the chemicals (serotonin) in the brain'. The claim made regarding the efficiency of the automated highway system was 'the automatic highway system can reduce the safety space between cars and increase the efficient use of the highway'.

Manipulation of Argument Stance

Experimental treatment on argument stance was administered to participants after they read the text explicating the claim and related explanations.

Proponent stance. These participants were instructed to act as proponents of the claim and practice argumentation according to the five-step argument structure (Table 1) provided by the experimenter.

Table 1. Argument structure provided to the proponents and opponents (in parentheses)

1. Give reasons to *support* (*reject*) the claim
2. Give evidence *in support of* (*counter to*) the claim
3. Give reasons that may be raised to *reject* (*support*) the claim
4. Give evidence that may be raised to *reject* (*support*) the claim
5. Respond to reasons and evidence raised in Steps 3 and 4 in order to maintain your claim

Opponent stance. These participants were instructed to act as opponents of the claim and practice argumentation according to the five-step argument structure (Table 1) provided by the experimenter.

Control group. Participants in the control group did not know anything regarding argumentation practice. Instead, they were asked to free recall, after reading the text, the content of the text as much as possible. After free recall, they were advised to review the text and check the accuracy of their recall. Because during argumentation practice, the experimental groups could consult the text for detail information, the free recall and review task was deliberately designed to encourage the participants in the control group to process the text deeper than the first reading. By so doing, it was hoped that their processing and comprehension of the text was at a level more equivalent to that of the experimental groups.

Participants were informed before the experimental treatment that there was a 20-min time limit for the activity (argumentation practice or recall) and that they would receive a notice 5 min before the time was up. However, in practice, all participants were allowed to finish their assigned activity. The five-step argument structures provided to the two experimental groups were the same except for the role they were assigned. The experimenter explained the meaning of each step to the participants and answered their questions before the argumentation practice began. The text and a copy of the argument structure and its explanations were provided during the argumentation practice.

Measures of Post-Argumentation Responses

Sound argumentation is the backbone of scientific reasoning. Therefore, one's argumentation performance is a good index of how one can reason scientifically. After the experimental treatment, participants in two experimental groups and the control group were asked to write down and explain their actual opinions regarding the claim in the post-test. The propositions made by the participants in their written protocols were analysed in order to extract the variables related to their acceptance of the claim, amount of knowledge inquiry activities, argument structure, number of falsifications, argument content, and method of refutation.

Acceptance of the claim. Before and after the argumentation treatment, participants were asked to rate, on a scale of 0–100%, how much they agreed with the claim

given in the text. Furthermore, participants had to express explicitly their position (agree or disagree) regarding the original claim in the post-test. Based on their stated position, participants' acceptance of the claim was classified into two categories: agree or disagree. However, some participants said they only partially agreed with the claim, and some modified their original position after argumentation. These two types of responses were classified as 'conditionally agree'.

Amount of knowledge inquiry activities. The extent of a participant's knowledge inquiry activities was measured by the number of new propositions they produced in their post-test written protocols, which went beyond what was provided in the texts. A proposition refers to an assertion regarding the relation between at least two concepts. New propositions refer to new factors or variables, or new relations not originally given in the text; for example, one participant wrote: 'Because 38% of subjects in placebo condition also showed improvement, it cannot be ruled out that depression may be related to psychological factors'.

Argument structure. Participants' arguments in the post-test were classified into the following categories:

- Supporting arguments—the number of statements that lent support to the claim raised in the text.
- Counterarguments—the number of statements that discounted the claim raised in the text.
- Rebuttals—the number of statements that were raised to discount counterarguments raised in the post-test.

Number of falsifications. Falsification refers to locating inconsistency between arguments or inconsistency between an argument and its supporting evidence (Hempel, 1965; Popper, 1968). Falsification ability is important in formulating and testing multiple hypotheses in scientific discovery. In this study, falsification is defined as one's ability to detect flaws in explanation and/or evidence which would discount the credibility of an argument. Participants' ability to falsify a claim was estimated by the sum of the numbers of counterarguments and rebuttals they made in their post-test written protocols.

Argument content. In order to analyse the basis of participants' arguments, each proposition in the participants' written protocols in the post-test was classified as evidence or as explanation. However, there were some arguments that could not be classified into either of these two categories. They were separately identified as alternative accounts of the claim or revisions to the claim that participants made at the beginning.

- Explanation—measured by the number of reasons that participants gave to support the claimed cause–effect relation; for example, '[An] automated highway system is

efficient because it can reduce the distance between cars, so more cars can be running in the highway at the same time'.

- Evidence—refers to the empirical manifestations of the claimed relation. These manifestations can be cases or incidents that participants experienced directly or observed indirectly. Alternatively, evidence can be statistical data cited by the participants from the text directly or quoted from other sources. For example, one participant said his son was diagnosed as having depression; however, it was caused by some psychological problem. After solving the psychological problem, the depression disappeared. Based on the data, the total number of evidences was further classified into four types: evidence directly quoted from the given text, evidence beyond the text, using personal experience as evidence, or using others' experiences as evidence.
- Alternative account of the claim—different claims raised to account for the observed phenomena other than the claim in the text; for example, depression can be caused by psychological problems or depression is a joint function of psychological stress and neurotransmitter imbalance.
- Revision of the claim—participants' efforts to modify their original claim in the conclusion. For example, one participant said at the end of argumentation that he would endorse an automated highway system if its side effects could be eliminated.

Method of refutation. Refutations are explanations or evidence raised to discount the validity of a claim. Counterarguments and rebuttals made by participants to the claim are both refutations. Not all participants were able to refute their own claim. However, when they did, the methods they used to refute the claim or the counterarguments to the claim were classified as assertion-based, argument-based, or alternative-based refutations, according to Shaw's (1996) classification.

- Assertion-based refutation—refuting an assertion made in an argument by the flaws in its supporting arguments. For example, 'The automated highway system can reduce the safety space between cars, *but* at the cost of depriving a driver's choice of speed'.
- Argument-based refutation—refuting an argument by indicating its (1) logical inconsistency in reasoning (e.g. 'The point that an automated highway system may increase car collision incidents does not shatter the validity of the claim that it can increase the efficiency of highway by reducing the safety space between cars'.) or (2) insufficient support from evidence (e.g. 'The finding that only 40% of patients taking serotonin treatment showed improvement in their depression did not strongly support the treatment effect or for the claim that a chemical imbalance is the cause of depression').
- Alternative-based refutation—based on proposing other possible accounts of observed phenomena. For example, 'depression is caused by environmental stressors such as poverty' or 'automated highway systems can only provide their expected benefits in crowded regions at certain periods of time'. The number of

alternative-based refutations was measured by the sum of the number of alternatives raised in argumentation and the number of revisions in the conclusion, and those already entailed by alternatives were excluded.

The scoring reliability for the content analysis ranged from 0.712 to 1.0 among three independent scorers, with an average of 0.90. Analysis of the entire corpus of the post-test written protocols was done using only one of the scorers.

Procedure

The experiment was run individually. Participants were presented with the depression issue or the automated highway issue in random order after receiving general instructions regarding the experimental procedure. They were told that the claim in the text was made by a university professor in the field and they had to read the text carefully to know the reasons behind the claim. When participants thought they had understood the issue, they were asked to rate, on a 100-point scale, how much they agreed with the professor's claim. Participants taking the proponent stance were then asked to argue *for* the claim according to the five-step argument structure provided to them. Similarly, participants taking the opponent stance were asked to argue *against* the claim according to the five-step argument structure requirements. Both argumentation practices were done in writing. A printed handout of the argument structure was provided to the participants during the argumentation practice. Participants in the control condition received no argumentation practice. Instead, they were asked to free recall whatever they remembered about the text. After the recall, they were asked to review the text in order to verify the accuracy of their recall and comprehension. There was a 20-min time limit for experimental group to engage in argumentation practice and for control group to make free recall, and they would be given a signal at approximately 5 min before the time was up. All participants finished the free recall in time. There were a few participants who did not finish argumentation within the allotted time. They were asked to finish their steps in argumentation practice.

After the argumentation practice or free recall, all participants were asked to rate the extent to which they endorsed the claim on a 100-point rating scale. They were then given another 20 min to write down their own position on the issue and explain their thoughts without any hint to the argument structure. No text or argument structure was available to participants during the post-test argumentation. The experiment took approximately 1.5–2.0 h to complete.

Statistical Analysis

In order to control for the effects of the issue and the possible interaction effect between the issue and argument stance, the 3 (argument stance) × 2 (depression *vs*. automated highway) repeated measure analysis of variance was used in statistical analyses in which argument stance was a between-subject variable and issue was a within-subject variable. Preliminary data analysis showed that there was little

interaction effect between the two variables. Significant main effects of argument stance on knowledge inquiry skills were followed by the least significant difference (LSD) method of multiple comparisons between means when the homogeneity of variance assumption was met, and the Sidak method was used when the homogeneity of variance assumption was violated. The α level was set at 0.05.

Results

Acceptance of the Claim

The results of 3 × 2 repeated analysis of variance on the 0–100% rating scale showed that participants endorsed the claim in the automated highway issue more than the claim in the depression issue prior to the argumentation practice (highway, $M = 72.39$, SD = 15.85; depression, $M = 64.06$, SD = 17.20), $F_{1,\ 66} = 9.03$, MSE = 263.26, $\eta^2 = 0.12$, $p < 0.005$. Similarly, they did so after the argumentation practice as well (highway, $M = 67.61$, SD = 20.07; depression, $M = 59.06$, SD = 19.93), $F_{1,\ 66} = 8.44$, MSE = 305.96, $\eta^2 = 0.11$, $p < 0.005$. Therefore, in the following analyses, the effects of argument stance on argumentation performance and knowledge inquiry was estimated with a type III sum of squares method to remove the variances explained by the issue and the interaction between the issue and the argument stance.

The results of repeated analysis of variance showed that the effect of argument stance on acceptance of the claim was neither significant prior to the argumentation practice, $F_{2,\ 66} = 1.78$, MSE = 284.66, $\eta^2 = 0.05$; nor after the argumentation practice, $F_{2,\ 66} = 2.174$, MSE = 484.726, $\eta^2 = 0.06$. When participants' post-argumentation responses regarding their position with regard to the claim were classified into agree, disagree, or conditionally agree, the results indicated that argument stance was not related to participants' position on the depression issue ($\chi^2 = 2.15$, df = 4), and a majority of the participants disagreed with the claim (control group, 50%; proponent group, 50%; opponent group, 52%). With regard to the automated highway issue, the argument stance was significantly related to participants' position ($\chi^2 = 10.54$, df = 4, $p < 0.03$). Seventy-three per cent of participants taking the proponent stance in the argumentation practice endorsed the claim (control group, 46%; opponent group, 32%), whereas 52% of participants who practised arguing the opposing stance disagreed with the claim (control group, 27%; proponent group, 18%). Because these two issues may belong to two ontological categories of knowledge—depression belongs to science while automated highways belong to technology—it appears that people are more easily persuaded by technology claims than science claims; however, practising argumentation using the opposition stance may reduce this tendency.

Argument Stance and the Amount of Knowledge Inquiry

In the post-test, when asked to express their own opinions regarding the issue raised in the claim, the mean number of total arguments made by the participants

was 6.67 (SD = 2.88), and the effect of argumentation stance was not significant (proponent group, $M = 6.54$, SE = 0.47; opponent group, $M = 7.30$, SE = 0.45; control group, $M = 6.15$, SE = 0.48), $F_{1,\ 61} = 0.15$, MSE = 0.68, $\eta^2 = 0.05$. However, in terms of how many new propositions were made by each group, the results of repeated analysis of variance indicated that the effect of the argument stance was significant, $F_{2,\ 61} = 4.04$, MSE = 7.82, $\eta^2 = 0.12$, $p < 0.02$. Multiple comparison between means (proponent group, $M = 4.98$, SE = 0.43; opponent group, $M = 6.24$, SE = 0.41; control group, $M = 4.63$, SE = 0.44) using the LSD method revealed that participants taking the opponent stance gave significantly more new propositions than either the control group ($p < 0.01$) or the proponent stance ($p < 0.04$). Moreover, the difference between the latter two groups was not significant.

Argument Stance and Argumentation Structure

Argumentation structure is the most important element for ensuring the quality of argumentation regarding a claim. A comprehensive examination of the claim must include not only the supporting arguments, but also the counterarguments and the rebuttals. Participants' post-test written opinions regarding the claim after the argumentation practice were classified as supporting the claim in the text (supporting argument), counter to the claim in the text (counterargument), or responding to a counterargument (rebuttal). Table 2 indicates that, in general, our participants gave less supporting arguments for the claims than the counterarguments. The results of analysis of variance showed that argument stance did not affect either the number of supporting arguments, $F_{2,\ 61} = 1.17$, MSE = 3.26, $\eta^2 = 0.04$, or the number of rebuttals, $F_{2,\ 61} = 1.80$, MSE = 1.32, $\eta^2 = 0.06$. However, there was a marginally significant effect on the number of counterarguments, $F_{2,\ 61} = 2.39$, MSE = 7.35, $\eta^2 = 0.07$, $p < 0.10$. Comparison between means by LSD method showed that participants taking the opponent stance gave significantly more counterarguments to the claim than the proponent group ($p < 0.04$); however, they did not differ significantly from the control group (see Table 2).

Table 2. Argument stance, argument structure, and falsification

		Control	Opponent	Proponent
Supporting argument	*M*	1.88	1.65	2.24
	SE	0.29	0.27	0.28
Counterargument (A)	*M*	3.65	4.57	3.56
	SE	0.43	0.40	0.42
Rebuttal (B)	*M*	0.63	1.09	0.95
	SE	0.18	0.17	0.18
Falsification (A+B)	*M*	4.28	5.65	4.31
	SE	0.43	0.40	0.42

Number of Falsifications

Falsification is considered essential in scientific reasoning (Popper, 1968). Both counterarguments and rebuttals involve the ability to falsify. When taking the sum of the number of counterarguments and the number of rebuttals as a measure of falsification ability in argumentation, the results showed that the effect of argument stance was significant, $F_{2,\ 61} = 3.66$, MSE $= 7.45$, $\eta^2 = 0.11$, $p < 0.03$. Comparison between means by LSD method showed that the group taking the opponent stance in argumentation made significantly more falsifications (see Table 2) than the control ($p < 0.02$) and proponent groups ($p < 0.03$). The latter two groups did not differ significantly.

Argument Stance and Argument Content

In order to constitute valid knowledge, one's claim must be supported by explanations that relate to other known knowledge and empirical evidence. The content of arguments can then be classified into explanations and evidence. The results of analyses of variance indicated that argument stance affected neither the number of explanations, $F_{2,\ 61} = 0.12$, MSE $= 4.51$, $\eta^2 = 0.004$, nor the total amount of evidence, $F_{2,\ 61} = 0.35$, MSE $= 3.07$, $\eta^2 = 0.01$. However, when we categorised the evidence into that directly cited from the text, that not cited in the text, personal experience as evidence, or others' experiences as evidence (Table 3), we found that argument stance had a significant effect on the use of evidence not cited in the text, $F_{2,\ 61} = 4.04$, MSE $= 0.24$, $\eta^2 = 0.12$, $p < 0.02$. Comparison between means using the Sidak method showed that participants taking the opponent stance cited significantly more evidence that was not mentioned in the text than either the proponent group ($p < 0.05$) or the control group ($p < 0.056$). Moreover, the argument stance was also significant for citing the experiences of others as evidence in argumentation, $F_{2,\ 61} = 4.56$,

Table 3. Argument stance and types of argument

		Control	Opponent	Proponent
Explanation	*M*	2.98	3.20	3.14
	SE	0.34	0.31	0.33
Evidence-total	*M*	1.38	1.59	1.69
	SE	0.28	0.26	0.27
Evidence-text	*M*	1.20	1.11	1.31
	SE	0.26	0.25	0.26
Evidence-else	*M*	0.05	0.30	0.05
	SE	0.08	0.07	0.08
Experience-self	*M*	0.13	0.09	0.02
	SE	0.06	0.07	0.06
Experience-others	*M*	0.00	0.09	0.31
	SE	0.08	0.07	0.07

MSE = 0.23, $\eta^2 = 0.13$, $p < 0.01$. Comparison between means using the Sidak method showed that the proponent group cited other people's experiences as evidence to their claim significantly more than the control group ($p < 0.02$).

In addition to explanations and evidence, participants' written protocols might also contain proposals for alternative accounts of the claim and/or revisions of their original claim. These propositions were summed and treated as alternative-based refutations and are analysed in the following section.

Methods of Refutation

The methods of refutation refer to ways used to find flaws in arguments, including unfounded assertions, errors in data collection or interpretation of data, invalid conclusions, etc. As Table 4 shows, there were relatively few argument-based refutations. Participants relied on assertion-based refutation in argumentation more than alternative-based or argument-based argumentation. The data showed that argument stance only made a difference in the use of alternative-based refutations (sum of the alternative accounts of the claim and revisions of the claim), $F_{2, 61} = 4.11$, MSE = 2.38, $\eta^2 = 0.12$, $p < 0.02$. Multiple comparisons between means using the Sidak method showed that the opponent group used significantly more alternative-based refutations (Table 4) than the proponent group ($p < 0.02$), but there was no significant difference when compared to the control group.

Conclusions and Discussion

In scientific investigations, one must possess the ability to entertain multiple alternative hypotheses as well as the ability to falsify a belief. Argumentation incorporates not only the demands for theory and evidence in the examination of a claim, but also critical examination of the pros and cons of a claim. In the scientific community, scientists engage extensively in argumentation in their knowledge inquiry activities in order to guard against their own blind spots. Therefore, argumentation is considered an indispensable scientific thinking skill one must acquire in the science classroom. The purpose of this study was to examine the effect of argument stance during

Table 4. Argument stance and types of refutation

		Control	Opponent	Proponent
Assertion-based	*M*	1.75	2.15	1.95
	SE	0.22	0.30	0.31
Argument-based, evidence	*M*	0.53	0.98	0.79
	SE	0.18	0.17	0.18
Argument-based, logic	*M*	0.43	0.48	0.43
	SE	0.16	0.15	0.16
Alternative-based	*M*	1.63	2.20	1.26
	SE	0.24	0.23	0.24

argumentation practice on scientific knowledge inquiry skills. Sixty-two college and graduate students were assigned to proponent, opponent, or control roles in order to receive argumentation practice on two scientific issues. After each argumentation practice, they were asked to announce their actual position regarding the issue and argue in its favour. The scientific knowledge inquiry skills were measured by the number of new propositions proposed, number of falsifications, and ways people argue.

Arguing in a sound manner is important for scientific inquiries; thus, this study analysed the effect of argument stance on argument performance. With respect to argument structure, the data showed that practising argumentation with a stance did not create any difference in participants' argumentation in terms of the number of supporting arguments or rebuttals. There were slightly more counterarguments raised against the claims by people who practised argumentation with the opponent stance ($M = 4.57$) over those who practised with the proponent stance ($M = 3.56$). However, the difference between the opponent group and the control group ($M = 3.65$) was not significant. Perhaps this is because most of our participants were graduate students who have been trained to be critical. The finding that participants raised more counterarguments than supporting arguments may lend some support to this inference. However, the relatively low number of rebuttals suggests that our participants' weakness in argumentation seems to lie in making rebuttals to counterarguments.

Only small differences were found with regard to the argument stance in terms of the types of content covered by participants' argumentations and methods of refutation. Similar to Shaw (1996), our data indicated that participants tended to argue by giving explanations. Only a small portion of their attention was devoted to examination of the evidence. However, argument stance may make a difference in what kind of evidence people use. Participants taking the opposition role during argumentation practice tended to cite more evidence that was not given in the texts than the control group, whereas the proponent group tended to cite other people's experiences as evidence more than the control group did. However, the differences between the proponent and opponent groups were not significant in both cases. It appears that argumentation practice, as either a proponent or an opponent, may enhance people's use of evidence to validate a claim.

In terms of the refutation method, the data showed that our participants generally relied on assertion-based refutation, although a few argument-based refutations were made. These findings are also similar to Shaw's (1996) finding. Assertion-based refutation primarily checks the validity of the knowledge employed in argumentation. In contrast, argument-based refutations check the validity of logical consistencies in reasoning. Apparently, finding logical inconsistencies in reasoning is difficult—even for undergraduate and graduate students. Unlike Shaw's finding, our participants also employed alternative-based refutation to some extent. As predicted, the participants who practised argumentation by taking the opponent's role raised significantly more alternative-based refutations than the proponent group, which implies that they became more aware of multiple causality in the interpretation of observed

phenomena. However, although the opponent group made more alternative-based refutations ($M = 2.20$) than the control group ($M = 1.63$), the difference between the two groups was not significant. It is very likely that the small sample size and the large and unequal within-group variances (standard deviations ranged from 0.67 to 2.19 among groups) rendered the statistical test less powerful.

Thus far, the results of the study suggest that argument stance plays a role on argumentation behaviours during argumentation, but the effect sizes were small. However, when we examine scientific knowledge inquiry skills in terms of the number of new propositions searched, alternative accounts proposed, or falsifications attempted, argument stance appears to have a greater impact. The data show that people who took the opponent stance in argumentation came up with a significantly higher number of new propositions, made more falsifications, and raised more alternative accounts than those in the proponent and control groups. Thus, opponent stance is instrumental in helping people look beyond information given in a text and encouraging critical examination of the text. These findings are corroborated by the positions participants claimed in their post-test argumentation, in which roughly twice as many people in the proponent group endorsed the claim made in the texts (52.5%) than the opponent group did (24%). Because there was no difference among the three experimental conditions in acceptance of the claim before the argumentation practice, these findings suggest that the demands of being an opponent may encourage people to think differently and think beyond the information in a given text. This can encourage deeper reflection on the content of science texts.

In summary, our findings suggest that taking a proponent stance in argumentation practice, which is very common in individual argumentation practice, did not differ significantly from the control group in most of the variables related to argumentation or scientific knowledge inquiry. The only exception is that the proponent group cited significantly more evidence from others' experiences to support their claim when compared with the control group. One possible explanation for these findings is that, in accord with the linguistic information presented in the text and the cognitive demand of text comprehension (Kintsch, 1998), it is natural for readers to assume the author's stance when reading a text, thereby limiting their thinking to what is explicitly said in the text. Subsequently, when asked to argue by taking a proponent's role, readers' memories of their first impression of the text are further reinforced. Even though readers are able to cite more evidence to support the claim made in the science text with argumentation practice, their memory search for related information is likely confined by the materials explicitly mentioned in the text. Consequently, falsification of what is given in the text becomes more difficult. Practising argumentation using an opposing stance may be a means to circumvent this detrimental primacy effect of human text processing.

Because argumentation plays a central role in science knowledge construction and validation, there are increasingly more scholars who advocate the importance of teaching and learning science as argumentation (e.g., Bricker & Bell, 2008; Kuhn, 2010). Therefore, how to design argumentation methods so as to benefit students most and how to evaluate argumentation performance is important for science

teachers (Erduran et al., 2004). However, only a few studies have begun to evaluate the teaching (Simon, Erduran, & Osborne, 2006; Simon, & Johnson, 2008) and learning of argumentation (Cross, Taasoobshirazi, Hendricks, & Hickey, 2008; Nussbaum, Sinatra, & Poliquin, 2008) in the science classroom. For science educators, the results of the present study provide direct behavioural evidence for the effects of argumentation on scientific knowledge inquiry. Besides, the methods we used to design argumentation materials, argumentation practice, and argumentation protocol analysis can be applied readily in classroom teaching or in research. For example, in a science classroom, teachers can, after presentation of a properly designed science issue, invite students to act as the opponent and practice argumentation individually. This method may compensate for the more time-consuming dyad argumentation or group argumentation. However, students' ability to understand the difference between explanation and evidence is a prerequisite for the success of the method. Therefore, to apply the five-step argument structure in teaching, teachers with younger students must provide ample examples to explain to the students the distinction between explanation and evidence. Finally, we have to caution readers that the observed effects of argument stance on scientific knowledge inquiry should not be generalised directly to dyad or group argumentation because of the complexity involved in group dynamics. However, how argument stance affects dyad or group argumentation is an interesting issue to be addressed in a future study.

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