The Effect of Varied Gender Groupings on Argumentation Skills Among Middle School Students in Different Cultures

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Abstract

The purpose of this mixed-methods study was to explore the effect of varied gender groupings on argumentation skills among middle school students in Taiwan and the United States in a project-based learning environment that incorporated a graph-oriented computer-assisted application (GOCAA). A total of 43 students comprised the treatment condition and were engaged in the collaborative argumentation process in same-gender groupings. Of these 43 students, 20 were located in the US and 23 were located in Taiwan. A total of 40 students comprised the control condition and were engaged in the collaborative argumentation process in mixed-gender groupings. Of these 40 students, 19 were in the US and 21 were in Taiwan. In each country, verbal collaborative argumentation was recorded and the students' post essays were collected. Among females in Taiwan, one-way analysis of variance (ANOVA) indicated that statistically a significant gender-grouping effect was evident on the total argumentation skills outcome, while multivariate analysis of variance (MANOVA) indicated no significant gender-grouping effect on the combined set of skill outcomes. Among females in the US, MANOVA indicated statistically significant gender-grouping effect on the combined set of argumentation skills outcomes Specifically, U.S. female students in mixed-gender groupings (the control condition) significantly outperformed female students in single-gender groupings (the treatment condition) in the counterargument and rebuttal skills. No significant group differences were observed among males. A qualitative analysis was conducted to examine how the graph-oriented computer-assisted application supported students' development of argumentation skills in different gender groupings in both countries. In each country, all teams in both conditions demonstrated a similar pattern of collaborative argumentation with the exception of three female teams in the US. Female teams, male teams, (the treatment condition) and mixed-gender teams (the control condition) demonstrated metacognition regulation skills in different degrees and with different scaffolding.

Introduction

In the United States during the past decade, the concept of science as argument has been emphasized in science education reforms (National Research Council, 2000). Recently, the *Next Generation Science Standards* (NGSS), built on *A Science Framework for K-12 Science Education* (National Research Council, 2012), identified "engaging in argument from evidence" (p. 12) as one of the essential eight science practices for students. With these reform efforts, students not only learn science from mastery of scientific concepts but also learn how to engage in scientific discourse (argumentation).

A number of researchers (Kuhn, 1993) have defined essential elements of argumentation: *position, reason, evidence, counterargument,* and *rebuttal*. A *position* refers to an opinion or conclusion on the main question that is supported by *reason*. *Evidence* is a separate idea or example that supports reason or counterargument/rebuttal. *Counterargument* refers to an assertion that counters another position or gives an opposing reason. A *rebuttal* is an assertion that refutes a counterargument by demonstrating that the counterargument is not valid, lacks as much force or correctness as the original argument, or is based on a false assumption.

Young adolescence is a critical age in which argumentation skills develop (Belland, Glazewski, & Richardson, 2011; Kuhn, Wang, & Li, 2010). Theoretically, young adolescents are supposed to be able to comprehend and construct arguments. However, empirical evidence does not support these expectations. Students usually provide insufficient or inconclusive evidence to support their arguments (Walton, 1996), have difficulty distinguishing evidence from explanation in support of a claim (Kuhn et al., 2008) or lack the ability to provide counterargument (Crowell & Kuhn, 2014).

In light of the reform efforts, researchers have used different approaches to develop curricula to help middle level students develop argumentation skills (Evagorou & Obsorne, 2013; Kuhn, Wang, & Li, 2010). More recent studies (Dwyer, Hogan, & Stewart, 2012; Hsu, Van Dyke, Chen, & Smith, 2015; Scheuer, Loll, Pinkwart, & McLaren, 2010) have explored the potential of graph-oriented computer-assisted applications and found a positive impact on argumentation skills. Research shows that visualizing arguments graphically through a graph-oriented computer-assisted application (GOCAA) enables students to see the structure of the argument, thus facilitating more rigorous construction and communication (Kiili, 2012). With the general positive impact of a GOCAA on argumentation skills, several studies (Carr, 2003; Easterday, Aleven, Scheines, & Carver, 2009) have explored the potential of a GOCAA to develop content knowledge. The findings were mixed. Easterday et al. (2009) conducted a study in which GOCAAs were used to teach causal reasoning on public policy problems. The study compared the effects of three conditions under which students were asked to analyze a problem. These conditions included: (a) problem presented as text only; (b) problem presented as text with an additional pre-made causal diagrams; and (c) problem presented as text with a GOCAA that students could use to actively construct a diagram from the text. Scores on the transfer test were significantly better for students in the third condition. Carr (2003), however, had contrary findings indicating that a graph-oriented computer-supported environment is not necessarily better than traditional methods in promoting learning outcomes. In Carr's study, second-year law students in a treatment group worked in small groups of three to four students on legal problems while having access to a GOCAA, QuestMap, while students in a control group worked without QuestMap, either alone or in small groups. The students in the treatment group did not outperform those in the control group on a final exam. One explanation is that, in practice, the application did not mediate the collaborative argumentation construction process. The students used the tool for transcription assistance instead of collaborating with one another through the application.

The above studies share a number of commonalities. They all involved the students in active construction of content knowledge in the authentic problem and collaborative argumentation, which reflects the critical elements of project-based learning (Fogleman, McNeill, & Krajcik, 2011). However, a number of studies (e.g., Carr, 2003) suggested that it is important to build a learning environment where students could use a GOCAA to mediate their argumentation process, which could have positive impact on content knowledge. Given the findings discussed above, it is concluded that middle level students who participate in a problem-based learning environment that incorporates a GOCAA would benefit their science knowledge and argumentation skills.

Research has explored female students' and male students' learning and interests in science and attempted to make curriculum and pedagogy more inclusive of both genders (Velayutham, Aldridge, & Fraser, 2012). With the advance of technology, female students and male students have more opportunities to engage in collaborative learning activities (Abnett, Stanton, Neale, & O'Malley, 2001). Therefore, recent research (Zhan, Fong, Mei, & Liang, 2015) studies the influence of gender groupings on students' learning outcomes in computer-supported collaborative learning.

In this study, we explored whether gender difference would be evident in the effect of gender-grouping (mixed vs. single-gender pairings) when students in two different cultures use a graph-oriented computer-assisted program for learning argumentation skills in a project-based learning environment. The findings could benefit the researchers and educators who are interested in the effective use of gender grouping strategy to mediate gender differences for young adolescents in the development of argumentation skills in cross-cultural computer-assisted collaborative learning.

Theoretical Framework

This section discusses the role of a GOCAA in supporting collaborative argumentation process in project-based learning environment. This section also discusses the impact of types of gender groupings and cultural differences on the collaborative argumentation process.

Use of a Graph-oriented Computer-assisted Application to Support Argumentation

In light of the reform efforts, researchers have used different approaches to develop curricula to help middle level students develop argumentation skills (Evagorou & Obsorne, 2013; Hsu et al., 2015; Iordanou, 2010; Kuhn, 2015). For example, Crowell and Kuhn (2014) developed a curriculum in which 56 students (6^{th}, 7^{th} and 8^{th} grades) in an urban middle school participated twice a week for three years. The Internet chatting application, Google Chat, supported the argumentation curriculum in the experimental group, while the control group participated in a traditional whole-class discussion. Argumentation skills of the experimental group outdistanced those of the control group.

More recent studies (Dwyer et al., 2012; Hsu et al., 2015; Scheuer et al., 2010) have explored the potential of graph-oriented computer-assisted applications and found a positive impact on argumentation skills. There are several graph-oriented applications (e.g., Digalo, Belvedere, Araucaria), each of which typically has a distinct way of constructing argumentation maps. However, there are many features common across these applications.

For example, contributions are displayed as boxes or nodes that represent argument components. Arrows represent relationships among the argument components (e.g., supports or refutes). As different components of arguments and their relationships can be distinguished via their visual appearance, learners are able to visualize and identify the important ideas in argumentations as concrete objects. These objects can then be pointed to, linked to other objects, and discussed.

Figure 1 shows the GOCAA used in this study.

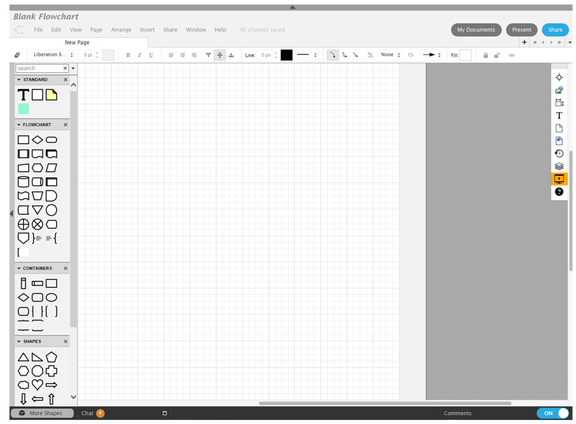


Figure 1. Screenshot of Lucidchart.

Issues in the Use of a Graph-oriented Computer-assisted Application to Support Collaborative Argumentation

Findings regarding the impact of a GOCAA to support collaborative argumentation on learning outcomes are inconclusive (Dwyer et al., 2012; Easterday et al., 2009; Suthers, Vatrapu, Medina, Joseph, & Dwyer, 2008). Collaborative argumentation in these studies is a form of social interaction, a critical element of a project-based learning environment and a critical element to support the development of individual argumentation skills (Andriessen, 2006; Crowell, 2011; Jonassen & Kim, 2010).

The effect of GOCAA project-based learning depends on whether you use it for synchronous or asynchronous collaborations and on the group size and composition. In previous studies, there have been no definitive conclusions about the use of a GOCAA to support collaborative argumentation in the curriculum and how different strategies could lead to postive impact on learning outcomes. The first issue is whether it is used for synchronous or asynchronous collaborations. One set of studies (Carr 2003; Weinberger, Stegmann, & Fischer, 2010) used a GOCAA to support synchronous collaborative argumentation in class and asychronous collaborative argumentation outside of the class. Another set of studies (Strijbos, 2011; Suthers et al., 2008) used a GOCAA to support solely asynchronous collaborative argumenation.

The second issue concerns the grouping strategy. Some studies (e.g., Carr, 2003) have used small groups of three to four students for graph-oriented, computer-assisted, collaborative argumentation activities. Others (e.g., Suthers et al., 2008) have used a pair of students. Moreover, the composition of the group members (e.g., the number of male vs. female students) has not been not clearly described in previous studies (Brotman & Moore, 2008).

The third issue involves the ways in which a GOCAA can be integrated to mediate collaborative argumentation. Carr (2003) found that a graph-oriented computer-supported environment is not necessarily superior to traditional methods in promoting learning outcomes. The students in Carr's treatment group did not outperform those in the control group on a final exam. Carr argued that the application did not mediate the collaborative argumentation construction process. The students used the tool for transcription aid instead of collaborating through the application. Therefore, in this study, the GOCAA was integrated to mediate collaborative argumentation synchronously and in groups of three to four students.

Impact of Types of Gender Groupings on Male and Female Students' Learning in Computer-assisted Collaborative Learning Environments

Research has explored female and male students' learning and interests in science and attempted to make curriculum and pedagogy more inclusive for both genders (Velayutham et al., 2012). With the advance of technology, female and male students have more opportunities to engage in collaborative learning activities (Abnett et al., 2001). Therefore, recent research (Sullivan, Kapur, Madden, & Shipe, 2015) studied the influence of gender groupings on male and female students' learning outcomes in computer-assisted collaborative learning. Ding, Bosker, and Harskamp (2009, 2011) studied whether gender differences were evident in the effect of gender grouping (mixed vs. single-gender pairings) in a computer-assisted collaborative learning environment in a secondary school. Students participated in a collaborative activity over a period of two weeks to solve physics problems. In pairs, students could only use the Internet-based computer program to communicate with another student. The program provides a computer-assisted collaborative learning environment through which each pair can use text messages and pictorial messages in the text-messaging box to communicate. Analysis of 96 secondary students' interactions revealed that a divergent pattern of knowledge elaboration led to female students' poor learning outcomes in mixed-gender pairs. Thus, females in single-gender pairs significantly outperformed females in mixed-gender pairs. But the same was not true for males.

Zhan and colleagues (2015) examined the effects of gender groupings on students' group performance and individual male and female students' learning achievements in computer-supported collaborative learning. Five hundred eighty-eight (588) undergraduate students enrolled in a digital design course were randomly divided into 147 four-student groups that fell into five categories according to the composition of group members' gender. Five categories are 4M (four males), 3M1F (three males and one female), 2M2F (two males and two females), 1M3F (one male and three females) and 4F (four females). Results indicated that for group performance, 2M2F and 4F groups significantly outperformed the other groups. This may be due to the fact that female students are better at planning and communication (Korobov, 2013; Tarim & Kyratzis, 2012). Thus they might engage in more discussion in the computer-supported collaborative learning, ultimately leading to a better outcome. The average performance score of the 2M2F groups was only 0.12 less than that of the 4F groups. They suggested that gender-balanced groups are also a good choice for achieving better group performance.

The results (Zhan et al., 2015) also suggested that for individual learning achievements, no significant difference was found in females among different gender grouping interventions; however, males in mixed-gender groups performed significantly better than those in single-gender groups. Male students might benefit more from the dynamic atmosphere created by mixed-gender communication, leading to better cooperation and enabling them to achieve better learning outcomes than male students in single gender groups.

Female students achieved better individual learning outcomes than male students in single-gender groups. This result is consistent with those of Brotman and Moore (2008), and indicates that working with same gender group members might be good for improving female students' learning performance, but is not so for male students. These findings provided evidence that female-only and balanced-gender groupings are two kinds of good grouping interventions that could be recommended for computer-supported collaborative learning, and male-minority groups should be avoided because they led to the worst group performance.

Impact of Cultural Differences on the Collaborative Argumentation Process

A number of scholars (Hofstede, 1997; Vatrupus & Suthers, 2010) have developed various definitions for culture. This study adopted Vatrupus and Suthers's (2010) definition of culture as cognitive schemas formed from the "interactive effect of the geography of that individual's upbringing and the formative experiences of his/her life" (p. 3). Countries in Asia such as Taiwan have inherited Confucianism in their culture. In Confucianism, teachers serve as authority figures and provide orders as well as instruction: they cannot be challenged or criticized by students (Heigmärtner, 2013). Students expect teachers to initiate communication and do not speak up unless invited by teachers. Students show respect for teachers outside class. Additionally, students are expected to learn how to participate fully in small groups. Formal harmony and face-saving are important (Lafifi, & Touil, 2010; Walker, Rummel, & Koedinger, 2009). In these countries, there are distinct expectations of male and female roles in society (Ding et al., 2009, 2011).

On the contrary, Western countries, such as the United States, are considered as small power distance societies (Hofstede, 1997) because teachers and students tend to share more equal power distribution. Students can challenge teachers and are encouraged to speak up. These types of countries are also considered individual societies. Students tend to focus on personal achievement and are encouraged to identify as well as discuss conflicts in their knowledge beliefs. Additionally, students feel comfortable in less-structured learning environments and explore answers on their own (Heigmärtner, 2013). These types of countries have a greater ambiguity in what is expected of male and female students. Research indicates that cultural differences might have an impact on the argumentation process (Kim, Anderson, Nguyen-Jahiel, & Archodidou, 2011; Hsu, Van Dyke, Chen, & Smith, 2016; Nisbett, Peng, Choi, & Norenzayan, 2001). Specifically, Hsu et al. (2016) explored the effect of a graph-oriented computer-assisted application on middle school students' argumentation skills in a cultural study and found a distinction between Taiwanese and U.S. teams in gender-based division of labor. In this study, the students were engaged in collaborative argumentation process in mixed-gender groupings in both countries. Compared to their female peers, male students in Taiwan tended to dominate the argumentation and control the keyboard and mouse. It may be that female students in Taiwan did not have the confidence to lead argumentation against the other U.S. team or perhaps assumed that male students should dominate the process. On the other hand, American students had more equitable distribution of tasks among male and female students, which reflects Western cultural norms of greater ambiguity in what is expected of male and female students. Thus, this study attempted to explore whether gender differences in the collaborative argumentation process of Taiwanese students would be mediated in same-gender groupings.

Research Questions

The following research questions were addressed:

1. What are the differences in argumentation skills (as measured by reason, evidence, counterargument, and rebuttal) between female students in same-gender groupings (the treatment condition) and female students in mixed-gender groupings (the control condition) in a GOCAA argumentation project-based learning environment in each country?

2. What are the differences in argumentation skills (as measured by reason, evidence, counterargument, and rebuttal) between male students in same-gender groupings (the treatment condition) and male students in mixed-gender groupings (the control condition) in a GOCAA argumentation project-based learning environment in each country?

If there was a difference in argumentation skills, in what ways would the graph-oriented computer-assisted program support students' development of argumentation skills in different types of gender groupings in each country?

In quantitative research questions 1 and 2, the independent variable is different types of gender groupings and the dependent variable is argumentation skill score. The dependent variable is measured on a ratio scale of measurement.

Method

Research Design and Participants

This mixed-methods (Creswell, 2013) study was conducted with 7th grade middle school students in suburban Chicago, US, and with 6th grade elementary school students in urban Tainan, Taiwan. Two classes in each country participated in the study. Within each country, each of the two classes was randomly assigned to either the treatment (same-gender groupings) or control condition (mixed-gender groupings). In the control condition, the students worked in teams of three to four, and each team included at least one girl and one boy. In the U.S. class, a total of 19 students (12 females and 7 males) comprised the control group. In Taiwan, a total of 21 students (14 females and 7 males) comprised the control group. Within each country the class assigned to the control condition consisted of seven mixed-gender teams. Each team in the control condition engaged in verbal collaborative argumentation among themselves and then argued against a corresponding team in the other country, using both verbal collaboration argumentation and the GOCAA (described in next section).

In the treatment condition, the students worked in teams of three to four same-gender members. In the U.S. class, a total of 20 students (13 females and 7 males) comprised the treatment group. In Taiwan, a total of 23 students (17 females and 6 males) comprised the treatment group. Within each country, the class assigned to the treatment condition consisted of six same-gender teams. Each team in the treatment condition engaged in verbal collaborative argumentation among themselves and then argued against a corresponding, same-gender team in the other country, using both verbal collaborative argumentation and the GOCAA (described in next section).

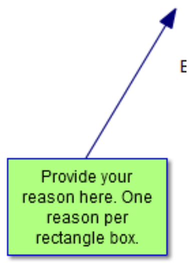
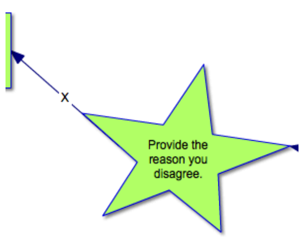
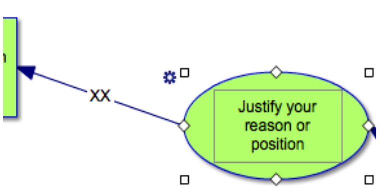
In the US, the students' ethnic backgrounds were diverse. Seventy percent (70%) came from Caucasian families, 10% were from Asian American families, and the remaining 20% were from African-American families or Hispanic-American families. In Taiwan, the students were ethnically homogeneous. In both schools, less than 20% of students came from low-income families. In this study "low-income students" refers to students in families receiving public aid, living in subsidized care, or eligible to receive free or reduced price lunches.

Graph-oriented Computer-assisted Application

In both conditions, each team used the graph-oriented computer-assisted program, Lucidchart, to present their arguments and argue against a team in the other country (Table 1). We used a number of criteria to select a potential application, such as capacity to support argumentation and expressiveness. We selected and tailored Lucidchart to meet the needs of this study. Lucidchart is a propriety tool and is developed for various learning purposes. A handout (see Table 1) that indicates argumentation elements by corresponding shapes and arrows and definition was provided to each student (Kuhn, 1993).

Table 1

Argument Elements by Corresponding Shapes and Arrows in Lucidchart and Definitions

Shapes and Arrows	Argumentation Skill	Definition
	Position (light bulb)	An opinion or conclusion on the main question
	Reason (rectangle and arrow)	A claim that supports the position
	Evidence (cloud and arrow)	A separate idea or example that supports a reason (or counterclaim or rebuttal)
	Counterargument (signified by star and “x”)	A claim that refutes another position or gives an opposing reason
	Rebuttal (signified by oval and “xx”)	A claim that refutes a counterargument by demonstrating that it is invalid, lacks as much force or correctness as the original argument or rests on a false assumption.

Procedure/Data Collection

All students had no prior topic knowledge about alternative energy and prior argumentation experience. The topic was new to all students. Therefore, at the beginning of the school year, the students in both conditions learned collaborative argumentation skills and learned the use of the GOCAA, Lucidchart. In the middle of the fall semester, all students in both conditions researched the assigned topic, alternative energy, for two weeks and developed either an iMovie video clip or a PowerPoint to present their findings. The potential sources of energy included solar, biomass, geothermal, hydrogen, hydropower, wind, and nuclear.

After the students' presentation, the students in each condition in both countries started the computer-assisted argumentation activity, and continued this for one week. During the first two days, these students were allowed 40 minutes each day to engage in verbal collaborative argumentation with their team members pertaining to the question, "Which form of alternative energy is the best?" After each team came to a consensus about a form of alternative energy, each team used the GOCAA, Lucidchart, to post reasons and evidence (Figure 2). Starting on the third day, inter-country argumentation was initiated. Each team from the US was paired with a corresponding country from Taiwan, with teams choosing distinct answers to the posed question paired together. Each team read their opposing team's reasons and evidence and provided a counterargument in Lucidchart. The teams then read the counterarguments, decided collaboratively how to rebut these counterarguments, then posted their rebuttals in Lucidchart. During these five days the students in both countries met online, talked through their postings in Lucidchart, and verbally argued against one another. Because of the time zone difference, the students in Taiwan came to school during the evening to participate in the activity.

Figure 2 indicates the Lucidchart argumentation map of a U.S. team and their corresponding Taiwanese team in same-gender (female) groupings (the treatment condition). The Taiwanese team selected solar (red) and the U.S. team selected biomass (orange). As indicated in Figure 2, for journal printing purposes, we converted the shapes in red to plain textboxes and the shapes in orange to plain textboxes with a thick border. Each team used the shapes and arrows (shown on Table 1) to represent its argumentation and argued with the opposing team in Lucidchart. In both countries, during the construction of argumentation maps in Lucidchart, the verbal collaborative argumentation of all teams was recorded with a digital camcorder.

After one week the students in both conditions from each country were asked to write post essays addressing the topic, "If the US/Taiwan could fund only one form of alternative energy, which one should you select?" Taiwanese students had the option to write their essays in Chinese. If they chose to do so, these essays were translated into English for analysis.

Quantitative Analysis of Essays for Argumentation Skills

There were a total of 83 student post essays in both countries. Based on Kuhn's (1993) definition of individual argumentation skills, the students' essays were scored for argumentation skills (reason, evidence, counterargument and rebuttal skills). The students had to follow correct logic to receive scores for each argumentation skill (Appendix A). For example, a reason must follow a position. An evidence must follow a reason. A counterargument must follow a reason and evidence. A rebuttal must follow a counterargument. When the students presented a single reason (e.g., "Solar energy can be used anyplace.") on their essay, they received one point. The same scoring procedure applied to evidence (e.g., "Solar panels can be installed everywhere."), counterargument (e.g., "If it is cloudy, it probably won't work."), and rebuttal skill (e.g., "My mom told me one time when I was swimming that it is easier to get burned when it is cloudy because the sun rays peek through the clouds when you don't even know it."). Each student's essay was scored individually. Each student received four argumentation scores and the total score for each argumentation skill was recorded in SPSS. The minimum score for each argumentation skills was zero. The researchers did not limit the maximum score for each argumentation skill. There were two raters of argumentation skill. The interrater reliability for the complete set of essays was 95%.

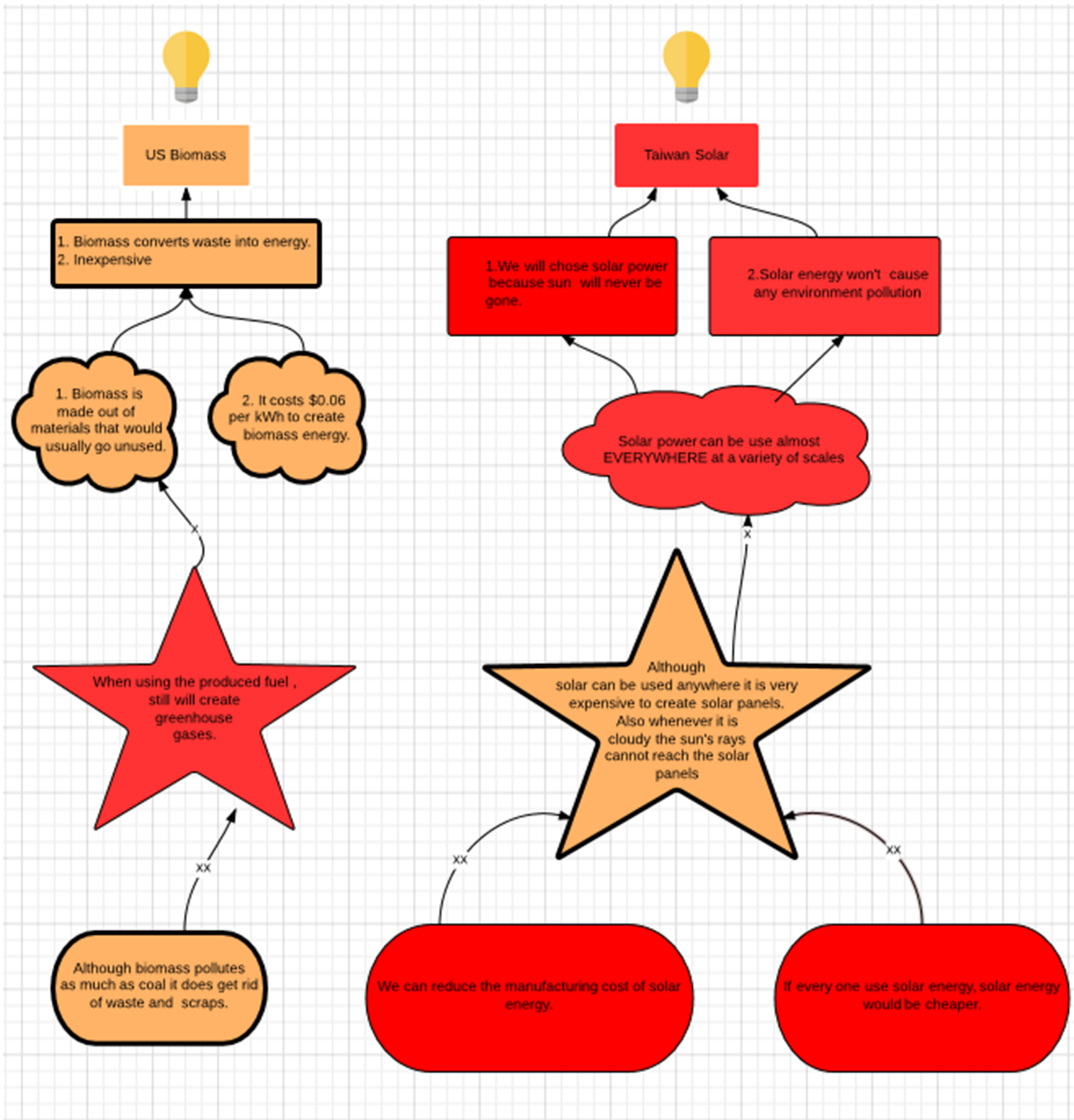


Figure 2. Argumentation map in Lucidchart constructed by a team in Taiwan and a team in the U.S.

Qualitative Analysis of Verbal Collaborative Argumentation Process for the Role of the Graph-oriented Computer-assisted Application

Kelly and Crawford (1996) developed the framework to analyze how the computer-assisted application supports the interaction among learners. In this study, we modified it to analyze how the GOCAA supports the collaborative argumentation process.

See Table 2 for the coding scheme.

Table 2

Coding Scheme

Categories	Code	Definition	Examples
Functions of computer application			
Constructing	Cons	Coding as a graph-oriented computer-assisted application is used to show learners' position, reasons or evidence.	A graph-oriented computer-assisted application is used to represent a position, reasons or evidence by inserting different shapes.
Exhibiting	Exh	Coding as a graph-oriented computer-assisted application is used as external representation.	A graph-oriented computer-assisted application shows different shapes to represent different argumentation skills.
Eliciting	Eli	Coding as a graph-oriented computer-assisted application serves as external representation to stimulate more responses from learners.	A graph-oriented computer-assisted application shows position to learners and learners respond by providing more reasons and evidence.
Acting as ally	Act	Coding as a graph-oriented computer-assisted application is used by learners to support their efforts to make a case.	A graph-oriented computer-assisted application is used as learners' ally to provide counterarguments or rebuttals.
Types of affordance in the argumentation process			
Demonstrating	Dem	Coding as learners use different shapes to represent different argumentation skills.	Learners post position, reasons, and evidence on a graph-oriented computer-assisted application.
Reading	Rea	Coding as learners use the external representation of a graph-oriented computer-assisted application to make sense of the process.	Learners read reasons and evidence provided by their corresponding team.
Responding	Res	Coding as learners provide more reasons and evidence to support their position.	Learners post more reasons and evidence to support their position on a graph-oriented computer-assisted application.
Claiming	Cla	Coding as learners provide counterarguments or rebuttal to make their case.	Learners post counterarguments or rebuttals on a graph-oriented computer-assisted application.
Regulating metacognition	Regume	Coding as learners consistently monitor and regulate the learning process by looking at the external representation.	Learners reflect on the argumentation process by looking at the argumentations on a graph-oriented computer-assisted application.

To help explain our coding process, we selected an excerpt that involved students' use of Lucidchart to support their verbal collaborative argumentation in a treatment team. Table 3 shows examples from three speakers (Tin-Tin, Wendy, Ning) arguing using Lucidchart (see Figure 2), along with the GOCAA's action, the nonverbal actions of three speakers, and the initial, researcher-assigned codes for the development of argumentation. The unit of analysis was idea units. We began looking for idea units by examining sentences in the transcriptions. When we assigned the initial codes, we focused on how argumentation skills were developed. This study examined the team members' interaction in the collaborative argumentation process. We transcribed a total of 36 teams' video clips of verbal argumentation process supported by Lucidchart and coded them. Kuhn (2015) addressed the lack of the in-depth analysis of the group interaction as a common issue in the collaboration studies. The method used in this study was to address this issue. The interrater reliability (percentage agreement) for the complete set of videos was 90%.

After assigning the initial codes, we continued to examine if the graph-oriented computer-assisted application's action and code for argumentation skills were associated. We identified patterns that a number of functions of the graph-oriented computer application were associated with types of affordance in the argumentation process as indicated in Table 4. We identified four functions of the computer-assisted application: (a) exhibiting, (b) helping to construct argumentation, (c) eliciting, and (d) acting as an ally. Table 5 indicates how each function relates to type of affordance in the argumentation process.

Additionally, when we coded the data we identified the distinction between the use of metacognition regulation in the collaborative argumentation process by the female teams and the male teams in the treatment condition in both countries. We assigned the code META to code transcripts of verbal argumentation process. We examined whether female and male teams in the treatment condition showed similar argumentation patterns during the construction of Lucidchart argumentation maps. Then, we compared all teams in both conditions in both countries.

Results

Research Question 1

ANOVA indicated that among female Taiwanese students a significant difference between conditions was evident for the total argumentation score [$F(1, 29) = 7.58$, $p = .01$], with students in the same-gender condition showing higher mean scores ($M = 16.53$, $SD = 4.06$) than students in the mixed-gender condition ($M = 11.14$, $SD = 6.72$). Cohen's effect size value ($d = 0.98$) suggested a large effect with high practical significance.

When the complete set of four argumentation skills was considered simultaneously, MANOVA showed no significant group difference [$F(4, 26) = 2.46$, $p = .07$]. However, a large effect size was observed ($\eta^2 = .28$). Given this large effect size, and given that non-significance may have been due to the relatively small sample size, we proceeded to examine canonical loadings. These loadings (i.e., structure coefficients: 0.16, 0.59, 0.81, 0.63 for reason, evidence, counterargument, and rebuttal, respectively) indicated that the treatment effect was relatively strong for reason, evidence, and counterargument. Follow-up univariate ANOVA, using a Bonferroni-adjusted significance level (.05/4 = .0125). However, significant effect of gender-grouping on counterargument only was found [$F(1, 29) = 7.24$, $p = .012$; $\eta^2 = .20$], with the mean counterargument score for the same-gender group ($M = 3.65$, $SD = 1.50$) higher than the mean score of the mixed-gender group ($M = 1.93$, $SD = 2.06$). Cohen's effect size ($d = 0.95$) suggested a high practical significance for this outcome.

When female students from the US were considered, ANOVA showed no statistically significant treatment effect was observed for the total argumentation scores [$F(1, 23) = 1.13$, $p = .30$], but MANOVA showed a statistically significant and large treatment effect on the combined set of argumentation skills [$F(4, 20) = 5.39$, $p = .004$; $\eta^2 = .52$]. Examination of the canonical loadings (i.e., structure coefficients; -.22, -0.49, 0.69, 0.58 for reason, evidence, counterargument, and rebuttal, respectively) indicated that the treatment effect was strongest for evidence, counterargument, and rebuttal. Follow-up ANOVAs on each skill considered separately, using a Bonferroni-adjusted alpha level (.05/4 = .0125), however,

Table 3

A Transcript of Three Students Working Together with Lucidchart and Corresponding Computer's Action, Nonverbal Action of Three Speakers, and the Researcher-assigned Codes

Students' Argumentation	Computer's Action	Nonverbal Action	Codes
Tin-Tin (F): Solar is the best type of energy. Let's insert a reason.	Allows students to use a shape to represent a reason.	Inserting a reason in Lucidchart.	demonstrating a position and reason
Wendy (F): We can take turn typing.	Allows students to use a shape to represent a reason.	Inserting a reason in Lucidchart.	demonstrating a reason
Tin-Tin (F): Let's type the first reason.	Allows students to use a shape to represent a reason.	Inserting a reason in Lucidchart.	demonstrating a reason
Wendy (F): Watch out for grammatical errors when we type.	Allows students to use a shape to represent a reason.	Inserting a reason in Lucidchart.	demonstrating a reason
Ning (F): Don't focus on the hot weather. People would argue that solar energy would not work in cold weather.	Allows students to use a shape to represent a reason.	Inserting a reason in Lucidchart.	demonstrating a reason
Tin-Tin: Evidence?	Allows students to use a shape to represent an evidence.	Inserting an evidence in Lucidchart.	demonstrating a evidence
Ning (F): Let's find a picture.	Allows students to use a shape to represent an evidence.	Inserting an evidence in Lucidchart.	Responding by finding evidence
Wendy (F): Let's look for disadvantages of biomass.	Shows the reason provided by the biomass team in the US.	Commenting on the screen.	reading other team's position, reason, and evidence
Tin-Tin (F): What are the bad things about biomass?	Shows reasons and evidence that support their position (biomass).	Looking at a position, reason, and evidence in Lucidchart.	generating a counterargument/counterarguments toward biomass
Wendy (F): When using the produced fuel, biomass still create greenhouse gases.	Allows students to use a shape to represent a counterargument.	Inserting a counterargument in Lucidchart.	demonstrating a counterargument
Tin-Tin (F): They are counterarguing us on the price of solar energy.	Shows a counterargument provided by the biomass team.	Looking at a counterargument in Lucidchart.	demonstrating a counterargument
Wendy (F): ...Let's look into the price of solar panels and rebut them.	Allows students to use a shape to represent a rebuttal.	Working on Lucidchart.	demonstrating a rebuttal
Tin-Tin (M): OK! Let's review and summarize advantages and disadvantages of solar and biomass energies.	Show the reason, evidence, counterargument and rebuttals of solar and biomass.		Summarizing and reflecting

Table 4

Computer Application's Function and Corresponding Type of Affordance in the Argumentation

Students' Argumentation	Function of Computer Application	Types of Affordance in the Argumentation Process
Tin-Tin (F): Solar is the best type of energy. Let's insert a reason.	Helping to construct argumentation	Demonstrating a position and reason
Wendy (F): We can take turn typing.	Helping to construct argumentation	Demonstrating a reason
Tin-Tin (F): Let's type the first reason.	Helping to construct argumentation	Demonstrating a reason
Wendy (F): Watch out for grammatical errors when we type.	Helping to construct argumentation	Demonstrating a reason
Ning (F): Don't focus on the hot weather. People would argue that solar energy would not work in cold weather.	Helping to construct argumentation	Demonstrating a reason
Tin-Tin: Evidence?	Helping to construct argumentation	Demonstrating evidence
Ning (F): Let's find a picture.	Eliciting	Responding
Wendy (F): Let's look for disadvantages of biomass.	Exhibiting	Reading
Tin-Tin (F): What are the bad things about biomass?	Exhibiting	Reading
Wendy (F): When using the produced fuel, biomass still create greenhouse gases.	Acting as ally	claiming
Tin-Tin (F): They are counterarguing us on the price of solar energy.	Exhibiting	Reading
Wendy (F): ...Let's look into the price of solar panels and rebut them.	Acting as ally	Claiming
Tin-Tin (M): OK! Let's review and summarize advantages and disadvantages of solar and biomass energies.	Exhibiting	Metacognition

Table 5

Association between the Functions of Computer Application and Types of Affordance in the Argumentation Process

Function	Type of Affordance
Construct	Demonstrating
Exhibit	Read, Metacognition
Elicit	Respond
Ally	Claim (Counterargument, rebuttal)

indicated that the mixed-gender group scored significantly higher on two of these outcomes (counterargument and rebuttal, M = 2.17, SD = 1.19 and M = 2.08, SD = 1.38 respectively) than the same-gender group (M = 0.85, SD = 0.69 and M = 0.85, SD = 0.69, respectively). Cohen's effect size (d = 1.35) suggested a large effect with high practical significance for the counterargument outcome. For the rebuttal outcome, Cohen's effect size value (d = 1.12) also suggested a large effect with high practical significance.

Research Question 2

The results of an ANOVA carried out using the total argumentation score as the outcome showed no statistically significant difference between treatment and control groups when Taiwanese male students were considered [$F(1, 11) = 0.15$, $p = .71$]. Similarly, MANOVA indicated no significant group difference on the combined set of four skills [$F(4, 8) = 0.45$, $p = .77$]. When male students from the US were considered, ANOVA indicated no significant group difference in total argumentation score [$F(1, 12) = 0.01$, $p = .93$], and MANOVA showed no significant difference on the combined set of skills [$F(4, 9) = 0.60$, $p = .68$]. Table 6 provides descriptive statistics for the total argumentation score and each of the four skills by condition and gender.

Research Question 3

As indicated in Table 7, a number of patterns were identified. First, the application helped all teams in both conditions to construct their argumentation by demonstrating their position, reasons, evidence, counterargument or rebuttals on Lucidchart in both countries.

Second, the application is an external representation that exhibits argumentation process. All teams in both conditions made sense of the process by reading the external representation in both countries. They could read position, reasons, and evidence provided either by their team or the other team. Moreover, all female teams (the treatment condition) in both countries looked at the application and showed a number of distinctive behaviors. For example, at the beginning of activity, the female students tended to look at Lucidchart and said, "Let's take a look at notes and find disadvantages and advantages of (type of energy)," and "Let's check out teacher's website for more information." They tended to share the workload during the collaborative argumentation process. They would say, "We can take turns typing." Or team members provided ideas to the team member who typed. During the construction of the argumentation map, they usually reminded themselves, "Stick to scientific facts not opinion." When they wrapped up the activity, the female students tended to summarize their argumentation process and looked for grammatical errors on the argumentation map in Lucidchart. These behaviors could be considered the use of metacognition regulation. Some metacognition regulation skills such as referring to the notes and resources are evident in mixed-gender teams (the control condition) but female students played a role in facilitating the use of these skills. For example, female students usually showed the notes to male students when they had a difficult time coming up reason and evidence at the beginning of the activity. Some metacognition regulation skills such as delegating tasks to team members for collaboration and summarizing the argumentation are not evident in mixed-gender teams (the control condition). Additionally, metacognition regulation is evident in male teams (the treatment condition) in both countries under the circumstances of teacher's scaffolding. The male students tended to leave their notes behind. When the teacher inquired where their notes and the handout of argumentation skills are, they would say, "I forgot. Let me find it." In all male teams, one to two boys were not engaged in the process. One to two boys were in charge of typing in the argumentation map in Lucidchart. When the activity ended, they rarely summarized and were rushed to end the activity, "OK! We are done. Yah!" The teachers had to constantly walk to them and reminded them to engage in the use of metacognition regulation skills in the process. Although it appears that all types of gender grouping teams demonstrated the metacognition regulation skills, they showed in different degrees and with different scaffolding in different types of gender groupings.

Third, the application elicits student response. Looking at the external representation of their positions, all teams in both conditions responded by providing reasons and evidence to support their position in both countries.

Table 6

Descriptive Statistics for Total Argumentation Scores and Skill Scores

		Taiwan Female			U.S. Female			Taiwan Male			U.S. Male		
Condition	Outcome	*n*	Mean	*SD*	*n*	Mean	*SD*	*N*	Mean	*SD*	*n*	Mean	*SD*
Treatment	Reason	17	4.94	1.25	13	2.85	0.69	6	3.67	1.63	7	2.57	1.51
	Evidence	17	5.00	3.20	13	2.77	1.42	6	3.50	2.59	7	1.29	1.38
	Counter-argument	17	3.65	1.50	13	0.85	0.69	6	2.00	1.26	7	1.43	.98
	Rebuttal	17	2.94	1.43	13	0.85	0.69	6	1.33	0.82	7	1.71	1.80
	Total Argument	17	16.53	4.06	13	7.31	1.75	6	10.50	2.88	7	7.00	2.58
Control	Reason	14	4.43	3.72	12	2.50	0.90	7	3.43	2.23	7	1.57	1.27
	Evidence	14	3.00	2.35	12	1.50	1.17	7	1.86	2.04	7	2.00	1.83
	Counter-argument	14	1.93	2.06	12	2.17	1.19	7	2.57	3.36	7	1.57	1.27
	Rebuttal	14	1.79	1.63	12	2.08	1.38	7	1.43	1.81	7	2.00	1.83
	Total Argument	14	11.14	6.72	12	8.25	2.63	7	9.29	7.18	7	7.14	3.48

Table 7

Comparison between Treatment and Control Teams in both Countries in Application Functions and Types of Affordances

Functions/Type Affordance	US			Taiwan		
	Mixed-Gender Control Teams	Female, Treatment Teams	Male, Treatment Teams	Mixed-Gender Control Teams	Female, Treatment Teams	Male, Treatment Teams
Constructing argumentation/demonstrating	v	v	v	v	v	v
Exhibiting/reading	v	v	v	v	v	v
Eliciting/responding	v	v	v	v	v	v
Acting as ally/claiming (counterargument)	v	v	v	v	v	v
Acting as ally/claiming (rebuttal)	v	v in one team	v	v	v	v
Exhibiting/regulating metacognition	v	v	v	v	v	v

Note. v= Present.

Fourth, when acting as an ally, the application is used by students to support their efforts to make a case by claiming a counterargument or rebuttal. Specifically, all teams in both conditions in both countries claimed a counterargument or counterarguments against their corresponding team to make their case. All teams claimed a rebuttal or rebuttals against a counterargument or counterarguments provided by their corresponding team with the exception of three female teams in the treatment condition in the US. When U.S female teams in the treatment condition argued with the Taiwanese, female teams in the treatment condition, U.S. female teams usually asked, "Would you like to counterargue against our energy?" and "You have to counterargue against what we said. So we can rebut." The Taiwanese female teams needed more time to comprehend the reason and evidence provided by the corresponding U.S. female team. Due to the time limit, the Taiwanese female teams did not get to the point where they inserted counterargument for the U.S team. The U.S female teams were not able to rebut any counterarguments.

Limitations

The sample size used in this study was relatively small, and this was a limitation. Another limiation was the length of the study. We implemented this study for one semester only.

Discussion

The present section is organized around the research questions. We used the qualitative findings from research question 3 to support the discussion of research questions 1 and 2.

Research Question 1 and 3

This study found a significant difference in argumentation skills between female students in the same-gender groupings (the treatment condition) and female students in the mixed-gender groupings (the control condition) in Taiwan. Taiwanese female students in single-gender groupings significantly outperformed the female students in mixed-gender groupings in counterargument skill. The findings are consistent with previous research on different types of gendering groupings in computer-assisted collaborative learning (Ding et al., 2009, 2011; Sullivan et al., 2015; Zhan et al., 2015). Previous research shows the positive influence of single-gender groupings on female students' learning outcomes in computer-assisted collaborative learning. In this study, the findings could be attributed to the gender and cultural differences. First, males tended to use visual representation questions instead of verbal explanation to answer female partners, whereas females tend to interact with others through verbal conversation (Buck, Beeman-Cadwallader, & Trauth-Nare, 2012). In this study, the GOCAA project-based learning environment allows the female students to use a combination of visual representation (Lucidchart) and verbal explanation (collaborative argumentation) and therefore affords female students more capability to engage in collaborative argumentation process (Baram-Tsabari, & Yarden, 2011; Brotman & Moore, 2008). Second, in communication research (Korobov, 2013; Stokoe, 2004; Tarim & Kyratzis, 2012), the studies identified that males tend to use competitive and adversarial speech to assert and maintain dominance, whereas females tend to have collaborative speech to create and maintain relationships of closeness and equality. Such difference might be augmented in Asian cultures. In Confucianism, males and females typically assume distinct roles in Asian cultures, which might have the impact on the collaborative argumentation process (Kim et al., 2007; Nisbett et al., 2001; Vatrupus & Suthers, 2010). Thus, the female students might feel more comfortable in engaging in collaborative argumentation in single-gender groupings than the female students in the mixed-gender groupings in this study. The above reasons might explain why female students performed better in counterarguments skill in single-gender groupings than in mixed-gender groupings in Taiwan.

On contrary, the U.S. female students who were in mixed-gender groupings significantly outperformed the female students in single-gender groupings in the counterargument and rebuttal skills. This may have been due to language. English was a second language for the Taiwanese students. Thus, while they entered text into the shapes, some of them used Google Translator to confirm whether their translation was correct or not and some asked the English teacher to confirm. This process was time consuming. Taiwanese female teams tended to be intimidated by the fast typing of American female teams. They usually said, “That is scary. They type so fast. They are catching up very soon.” Three of four Taiwanese female teams were stuck on the reasons and evidence posted by the U.S. female teams because they could not comprehend U.S. female teams’ reason as well as evidence and asked the teachers to explain. When it came to verbal argumentation supported by the GOCAA, the U.S. female teams understood that English is not Taiwanese students’ native language and Taiwanese female students were very nervous. The U.S. female teams always waited for Taiwanese female students patiently to provide reason, evidence, and rebuttals in Lucidchart. They listened to the Taiwanese female teams’ argumentation as well. However, the U.S. female teams had to prompt the Taiwanese female teams to raise counterarguments against them. Due to limited time of online argumentation activity, three of four U.S. female teams did not have the opportunity to respond to the counterargument provided by the Taiwanese female teams and rebut them. This might reflect female’s cognitive style that tends to emphasize understanding, empathy, and cooperation. From the perspective of culture differences, U.S. students had more equal distribution of tasks among male and female students, which reflects the Western culture of having a greater ambiguity in what is expected of male and female students. Thus, compared to mixed-gender groupings, U.S. female students had less opportunities to respond to counterargument and provide rebuttals than in single-gender groupings in this study (Baram-Tsabari & Yarden, 2011; Brotman & Moore, 2008), which explains why the female students in mixed-gender groupings significantly outperformed the female students in single-gender groupings in the counterargument and rebuttal skills in the US.

Research Question 2 and 3

This study found no significant difference in argumentation skills between male students in the same-gender groupings (the treatment condition) and male students in the mixed-gender groupings (the control condition) in each country. In each country, all teams in different conditions demonstrated a similar pattern of argumentation process; however, female teams, male teams (the treatment condition), and mixed-gender teams (the control condition) demonstrated the use of metacognition regulation skills in different degrees and with different scaffolding in the collaborative argumentation process with the support of GOCAA. In mixed-gender teams (the control condition), each team has male and female students and female students tended to influence male students in the use of metacognition regulation skills. Previous findings (Asterhan, Schwarz, & Gil, 2012; Ma & Yuen, 2011) suggested that the poor use of metacognition regulation skills by male teams might result in the poor quality of the degree of participation, kind of participation, and experience of participation in a computer-assisted collaborative learning environment, which can lead to poor learning outcomes. However, male teams in the treatment condition showed use of metacognition regulation skills under the circumstances of teachers’ scaffolding.

In science education, extant research that has addressed the support of students’ scientific argumentation skills has focused on the written form, such as the Science Writing Heuristic (Cavagetto, Hand, & Norton-Meier, 2010). Recently, researchers have taken different approaches to develop students’ scientific argumentation skills such as engaging students in argumentation talk, and these researchers have portrayed argumentation as a social process of constructing, supporting, and critiquing the claims for the purpose of developing shared knowledge (Berland & Reiser, 2009; Ryu & Sandoval, 2012). Along with this line of research, scholars also caution that more work is needed to understand types of support needed to engage students of different cultures in this social process. This study advances knowledge of the importance of communication styles and modes of knowledge representation when involving students of different gender groupings and of different cultures in the collaborative argumentation process. As indicated in this study, using a GOCAA to support collaborative argumentation process has the potential to mediate differences between female and male students from different cultures in their development of argumentation skills. Yet, researchers need to explore ways (e.g., teacher guidance) to address male students’ lack of metacognition skills in the collaborative argumentation process in different cultures.

Implications and Conclusion

The findings of this study showed that the male teams in both countries tended to use metacognitive regulation skills to a lesser extent than female teams to regulate their collaborative argumentation process supported by a GOCAA. Further studies are needed to explore what causes male students to fail to use their metacognitive skills and the affordances of the GOCAA. For example, conducting a qualitative research study that incorporates in-depth interviews with the male students could provide insight into a number of questions. Do male students have difficulty in impulse control? Do they find other male students' competition distracting? Are they aware that they are failing to be strategic in their work? When they work with the female teams, do they notice the difference in the quality of argumentation maps? This study suggested that female same-gender groupings benefit Taiwanese (Asian) female students in the argumentation skills in cross-cultural collaboration and could be recommended for the GOCAA project-based learning environment. For male students in both Taiwan and the US, a mixed-gender grouping is one type effective grouping treatment that could be recommended for the GOCAA project-based learning environment.

Additionally, this study was conducted with a small sample size. This study could be replicated with larger sample size and the results compared. Also, this study was conducted within one semester for one science topic. Longitudinal studies over a longer period are needed to examine how different types of gender groupings affect female and male students in argumentation skills in different cultures.

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Appendix A
Correct Logic for Scoring Argumentation Skills in Individual Essay

Example 1:
(Indicate a Position)-(Indicate Reasons)-(Indicate Evidence)-(Indicate Counterarguments)-(Indicate Rebuttals)

Example 2:
(Indicate a Position)-(Indicate Reasons)-(Indicate Evidence)-(Indicate Counterargument)-(Indicate Rebuttal))-(Indicate Counterargument)-(Indicate Rebuttal)