A Case Study Exploring Learning Experiences in a Science Summer Camp for Middle Level Students From Taiwan and the United States

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Abstract

The purpose of this qualitative case study was to explore how young adolescents participated in various activities in a science summer camp. A total of 26 Taiwanese students and 16 U.S. students participated in a one-week “Argue like a Scientist” summer camp. Based on the design features of project-based learning, this science summer camp aimed at engaging the students in collaborative scientific argumentation about alternative energies and involved them in various activities related to alternative energies such as a field trip to an ethanol plant and a hands-on project building a solar car. All activities, including the students’ collaborative argumentation, were recorded. Their post-camp surveys were also collected. Three themes emerged from the data analysis. First, regardless of cultural background, age, or gender, all students actively constructed their understanding of alternative energies by participating in all hands-on activities: conducting research on different types of alternative energies, building their solar cars, and racing their solar cars. Second, regardless of cultural background, age, or gender, all students were engaged in the discussion and exploration of a real-word meaningful problem: “Which alternative energy is the best?” Third, regardless of cultural background, age, or gender, all students engaged in the social interaction with the support of a cognitive tool. This study concluded that the summer camp incorporated four principles of project-based learning (active construction, situated learning, social interaction, and cognitive tool), showing the potential of engaging students in science.

Keywords: collaborative argumentation, computer-assisted application, science summer camp, project-based learning

Introduction

Informal science education involves lifelong learning in science, technology, engineering, and mathematics (STEM) that takes place across a wide variety of designed settings (e.g., summer programs) outside of the formal classroom and plays an important role in promoting science learning for preK-12 and beyond. Research (e.g., National Science Teachers Association [NSTA], 2012)
indicates that the learning experiences delivered through informal science education can provide opportunities to broaden and deepen students’ engagement in science and spark students’ interest in science as well as their interest in the pursuit of science in school and their daily life. Over the last ten years, investments in an infrastructure for informal science education have resulted in significant growth in the number and variety of resources and the depth of expertise available to the science education community (Bell et al., 2016). Nevertheless, in terms of informal science learning programs such as summer programs, a number of reports from the National Research Council (NRC, 2015) have called for more effort to contribute to the body of knowledge regarding effective programs for science learning as well as the evaluation of individual programs.

Among the informal science learning settings, summer camps are popular in the United States. Various summer science programs are offered for precollege students with an aim toward increasing the involvement of young people in science. The advantages of the summer programs are numerous, including improving students’ skills and confidence in science and ultimately retaining students in the science pipeline throughout high school and colleges (Bhattacharyya et al., 2011; Urness & Manley, 2013).

Summer programs are typically designed in a way that allows students to form connections between the science they have encountered in their textbooks and the science required to solve real-world problems (Leblebicioğlu et al., 2011). The design features of summer science camps vary in topics, characteristics, and scope, depending on the age group.

To provide nuanced insight into young adolescents’ learning experiences, the current study explored learning experiences at a summer science camp for middle level students from Taiwan and the United States. Drawing on multiple data sources such as observations via video-recording and an exit survey, the researchers sought to understand the dynamics of the collaborative argumentation process with the support of the graph-oriented computer-assisted application in a project-based learning environment. The research question was: What are young adolescents’ learning experiences in various activities in a summer camp?

**Review of Research**

Middle level students’ learning experiences in summer camps remain an under-studied area. Sheridan et al. (2011) studied the impact of a summer science camp that focused on chemistry modules based on middle level students’ interest in science. They collected the exit survey data to look for an increase in the students’ interest in science. A number of features contributed to an increase in students’ interest in science and high return rate of enrollment the following year, such as hands-on activities, college student camp assistants, modules co-developed by college science and education professors, and a differentiated instruction model.

Urness and Manley (2013) conducted a week-long summer camp to promote interest in computer science among middle level students. The camp primarily taught programming concepts using the App Inventor for Android programming environment. Positive survey feedback indicated an increase in the students’ interest in computer science.

Other researchers have also examined the impact of summer camps on students’ science content knowledge and their motivation in science. Sezen Vekli (2013) randomly selected 10 out of 48 student participants to conduct a descriptive qualitative case study exploring the effectiveness of summer science camp experience on middle level students’ content knowledge and interest in biology. The instruments included a reflective journal, pre- and post-questionnaires, observations and students’ field notes. The findings showed that students’ understanding of biology content knowledge developed during science camp. In addition, the science camp had positive impact on their interests in biology, their career decisions, and their perceptions regarding biology.

In a mixed-method study, Weinberg et al. (2011) examined the effects of four experiential summer programs on the motivation of 336 middle level students regarding mathematics and science. Multiple data collection tools were used, including the pre- and post- Science and Mathematics Student Attitude Assessment Survey, student interviews, and an online instructor questionnaire. The findings indicated the students were generally positive and had relatively high mathematics and science motivation. However, Weinberg et al. pointed out that the high level of self-reported motivation in learning mathematics and science at the beginning of the program may explain the lack of detectable changes on self-reported student motivation measure at the end of the program. **Conceptual Framework**

The conceptual framework used to develop the summer camp in this study included elements of
project-based learning, collaborative argumentation, and use of a graph-oriented computer-assisted application to support collaborative argumentation. We also considered cross-cultural influences on project-based learning.

**Project-Based Learning**

The roots of project-based learning can be traced back to the work of educator and philosopher John Dewey (1959) in the Laboratory School at the University of Chicago. In the last decade, project-based learning has been widely applied in science classrooms to support students’ development of a deeper understanding of science concepts (Fogelman et al., 2011).

Project-based learning has a number of key features: active construction, situated learning, social interaction, and cognitive tools (Krajcik & Blumenfeld, 2006). Project-based learning allows students to gain a deeper understanding of materials when they actively construct their understanding by working with and using ideas (i.e., active construction). Derevenskaia (2014) studied the impact of the active construction method on high school students in learning environmental science. The task of assessing the ecological conditions of the river Kazanka (the city of Kazan) was given to a group of students. During the project, the students were involved in solving problems close to ones solved by experts. Use of the active construction method allowed the students to learn the ecologic and biological disciplines more effectively and deeply, to form a systematic approach for research work, and to develop practical skills. It also helped to develop students’ awareness of their own regional environment. Thus, the findings of this study showed the promise of an active construction method for supporting students’ learning science. Yalcin (2016) also examined the effect of active learning-based summer camp activities on young adolescents’ perceptions toward scientific knowledge and found an increase in the scientific knowledge at the end of the program.

In project-based learning, students engage in real-world and meaningful problems similar to the activities in which adult professionals such as scientists engage (i.e., situated learning). Situated learning allows learners to acquire information in a meaningful context and relate to prior knowledge and experiences (Brown et al., 1989). Contextualizing the learning enables learners to see the value and purpose of the activities they are asked to do. Sadler (2009) used situated learning as a theoretical framework to develop classroom communities of practice based on engaged citizenship relative to the negotiation of socio-scientific issues (SSI). The aim of this approach was to develop students’ practices and dispositions to better prepare them for active participation in society, particularly in the context of science-related social issues.

Social interaction is another important feature that allows students to work with others such as peers and teachers to construct shared knowledge. Cognitive tools such as computer-assisted applications can augment and build on what learners learn. In project-based learning, cognitive tools are used as scaffolds to support learning. With the advance of technology, numerous researchers (e.g., Moursund, 2003) have proposed adding technology to augment the effectiveness of a project-based learning environment. Thus, the following sections discuss collaborative scientific argumentation as a form of social interaction and address how a graph-oriented computer-assisted application served as a cognitive tool for supporting the collaborative argumentation process in a project-based learning environment.

**Collaborative Argumentation**

Recently, the Next Generation Science Standards (NGSS Lead States, 2013) identified scientific argumentation as one of the eight essential science practices for students. Scientific argumentation is a form of logical discourse that involves arriving at an agreed-upon position among members of a group (Andriessen, 2006) and is practiced when scientists build on and/or refute one another’s theories and empirical evidence to arrive at scientific conclusions. Sampson et al.’s (2012) view of scientific argumentation is consistent with earlier views (e.g., Andriessen, Baker & Suthers, 2003), but they expanded the definition of scientific argumentation and viewed it as a social and collaborative process of proposing, supporting, evaluating, and refining ideas to make sense of a complex problem to advance knowledge.

A number of researchers (e.g., Kuhn, 1993; Walton, 1996) have defined essential elements of argumentation: position, reason, evidence, counterargument, and rebuttal. Position refers to an opinion or conclusion about 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. 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.

In light of the reform efforts, researchers have used different approaches to develop curricula to help middle level students hone argumentation skills in formal learning environments (Iordanou, 2010; Kuhn, 2010). For example, Crowell and Kuhn (2014) developed a collaborative argumentation curriculum in which 56 sixth, seventh, and eighth graders attending an urban middle school with a predominantly Hispanic and African-American lower and lower-middle socioeconomic student population participated in an experimental group twice a week for three years. The control group participated in a traditional whole-class discussion. The argumentation skills of the experimental group outdistanced those of the control group. While most studies on scientific argumentation have focused on the context of formal learning environments, research on the integration of scientific argumentation in informal science learning environments is needed.

Young adolescence is a critical age in which argumentation skills develop (Belland et al., 2011). Theoretically, young adolescents should be able to comprehend and construct arguments; however, empirical evidence does not confirm 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, or lack the ability to provide a counterargument (Crowell & Kuhn, 2014). When asked to generate argumentation for or against their own positions, students typically provide more reasons to support their own position and fail to identify points of conflict to rebut others’ argumentation (Crowell & Kuhn, 2014).

In the middle grades, science becomes more difficult and abstract. But according to Piaget’s (1972) four stages of cognitive development, young adolescents should reach the fourth stage of cognitive development, the formal operational stage, and be able to logically use symbols related to abstract concepts such as science. They should be able to think about multiple variables in systematic ways, formulate hypotheses, and consider possibilities. They should also be able to comprehend abstract relationships and concepts. However, young adolescents progress through the cognitive development stages at different rates, and some might still be at the third stage of cognitive development, the concrete operational stage. They cannot think abstractly or hypothetically. Scientific argumentation can serve as a form of social negotiation and is a powerful force in the cognitive development of learners (Driscoll, 1994). Similarly, Bruner (1986) explains that learning is a communal activity or sharing of culture. By engaging in social negotiation, learners have the opportunity to share their understanding with others while others do the same with them. This provides multiple perspectives for each learner through a negotiation process among learners, resulting in better understanding and learning outcomes.

Use of a Graph-Oriented Computer-Assisted Application to Support Collaborative Argumentation

Research shows that visualizing arguments graphically enables students to see the structure of the argument in a graph-oriented computer-assisted application, thus facilitating more rigorous construction and communication (Kiili, 2012; Scheuer et al., 2010). There are a number of graph-oriented applications (e.g., Digalo, Belvedere, Araucaria), each of which typically has a distinct way of constructing argumentation maps. However, a number of features are 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 argumentation as concrete objects. These objects can then be pointed to, linked to other objects, and discussed.

More recent studies (Dwyer et al., 2012; Scheuer et al., 2010) have explored the potential of graph-oriented computer applications and found a positive impact on argumentation skills. A graph-oriented computer-assisted application is an example of a cognitive tool (Pea, 1985). Such an application has the potential to help learners accomplish cognitive tasks and leads to the development of argumentation skills. Cognitive tools could serve four purposes: (a) support cognitive processes such as memory and metacognitive processes; (b) share the cognitive load by providing support for lower level cognitive skills so that resources are left for higher order thinking skills; (c) engage in cognitive activities that would
not be possible otherwise; and (d) generate and test hypotheses (Lajoie & Derry, 2013). These four purposes are not mutually exclusive. In a number of studies (Carr, 2003; Dwyer et al., 2012; Easterday et al., 2009), a graph-oriented computer-assisted application served the first and second purposes for supporting the development of argumentation skills.

Dwyer et al. (2012) conducted a study in which 74 undergraduate psychology students were allocated to conditions either with or without the infusion of a graph-oriented computer-assisted e-learning environment. The students in the infused environment showed significantly larger gains in argument analysis than the control group. In their study, the students used the graph-oriented computer-assisted application to build their own argumentation over eight weeks inside and outside of the classroom. The visual representation of a graph-oriented computer-assisted application supported cognitive processes and allowed the students to make their thinking visible (memory) and monitor the development of argumentation (metacognition). Additionally, the visual representation also shared the cognitive load by providing support for lower level argumentation and afforded the students with more resources a higher level of argumentation.

**Cross-Cultural Influence on Project-Based Learning**

The summer camp that is the focus of this study included a cross-cultural aspect because the participants came from both Taiwan (N = 26) and the United States (N = 16). Project-based learning requires students to engage in open communication to optimize educational outcomes from student-centered, collaborative, small group learning environments. However, the interaction in project-based learning can pose challenges, particularly for Asian students (Chao et al., 2012; Zhou & Shi, 2015). Specifically, implementation of project-based learning involves active learning with open communication, which may be different from the Asian communication style generally dominated by cultural reticence and being shy about saying what is known or felt (Gwee, 2008). For example, Japanese students might wait to express what they truly think and speak about their perspectives because being polite and tactful are key characteristics of their communication. Similarly, Zhou and Shi’s qualitative case study took a cross-cultural perspective to explore Chinese students’ development of creativity in engineering in a project-based learning environment. They found that learning how to think independently and how to actively collaborate with their peers was new to the students because they were used to respecting the teacher’s authority without any questions and learning through lectures and demonstrations.

The other challenge was Asian students’ proficiency in English (Frambach et al., 2014; Gwee, 2008). Although English textbooks are widely used in many medical schools across Asia, English is not the native language nor is it the main language of instruction in many Asian countries. In their qualitative case study, Frambach et al. (2014) clearly observed that the Asian students tended to keep silent in the communication process because they felt their English was not proficient enough. As a result, it was challenging for the students to engage in meaningful and optimal discussion during the project-based learning process.

**Methods**

This study used a qualitative research methodology, specifically case study research design (Stake, 1995), to explore answers to the research question. The first researcher was responsible for sampling the participants, collecting the data, and analyzing the data, while the second and third researchers assisted with the data analysis process.

**Participants and Context**

A total of 26 Taiwanese students and 16 U.S. students participated in a four-day “Argue Like a Scientist” summer camp held in a large university in Midwestern United States. The summer science camp was open to students in the upper elementary level and middle level in both the U.S. and Taiwan. The students’ age ranged from 10 to 15; 26 Taiwanese students (10 females and 16 males) were recruited by the teachers in a Taiwanese school based on their interest in learning science and their willingness to receive training in English. The students’ airline tickets were covered through a grant, but their parents paid for food and lodging. The composition of the students’ ethnic background was homogeneous. The majority of them came from middle-class families. Although English was not their native language, the majority of the students had learned English at an early age and a few of them had experience studying in the U.S. Before they participated in this summer camp in U.S., they received intensive training in English.
The first researcher also selected 16 American students (9 females and 7 males) based on their interest in science. The composition of the students’ ethnic backgrounds was diverse, including three African Americans, three Hispanic Americans, two Asian Americans, and eight Caucasians. The majority of them came from middle-class families, while four of them came from low-income families. We waived the tuition for students from low-income families.

Procedure

The summer camp design was grounded in the principles of project-based learning: active construction, situated learning, social interaction, and cognitive tool. The summer camp took place from Monday to Thursday; each day started at 8:00am and ended at 4:30pm. On the first day, the students were assigned into a small team of four to five persons based on their age and gender. There were four female teams, five male teams, and one mixed-gender team. All teams engaged in situated learning about an assigned alternative energy source and developed an iMovie video clip to present their findings (i.e., active construction). The potential sources of energy included solar, biomass, geothermal, hydrogen, hydropower, wind, and nuclear.

Starting from the second day, the teams were engaged in the collaborative argumentation activity, which involved social interaction. The first two researchers provided brief instructions for the activity. They designated a leader in each team, who was responsible for facilitating collaborative argumentation. They explained the difference between dominating and facilitating and ensured every student could contribute. The first two researchers constantly rotated among the teams and monitored their progress.

On the second day, the first two researchers instructed students to argue their position, reason, and provide evidence with their team members verbally. Each team was engaged in verbal collaborative argumentation with their team members regarding the question, “Which form of alternative energy is the best?” After each team came to a consensus on a position about which form of alternative energy was the best, each team posted their position, reasons, and evidence using Webspiration, the graph-oriented computer-assisted application that served as the cognitive tool (Figure 1).

Webspirations was chosen due to its appealing design to middle level students and a functionality that allows students to construct their argumentation using
shapes and arrows. Figure 2 indicates argument elements by corresponding shapes, arrows, and definitions (Kuhn, 1993). Each team was paired with another team.

Starting on the third day, the first two researchers instructed students to provide counterarguments to other teams’ positions as well as rebuttals to defend their position. Each team read the other teams’ reasons and evidence and provided counterarguments in Webspiration. Then each team read the counterarguments, continued to argue how to rebut the counterarguments, and posted their rebuttals in Webspiration. Figure 1 indicates the argumentation map of a representative class. As indicated in Figure 1, the hydropower team was assigned to engage in collaborative argumentation with the biomass team. Each team indicated its position by inserting its team-selected alternative energy below a light bulb. During class time, each team used the shapes and arrows on Figure 2 to represent its argument and argue with other teams through Webspiration. Since each team was designated a quiet corner in a separate classroom, the teams were not able to verbally argue with students on other teams.

This study attempted to have minimal researcher intervention; thus, the first two researchers only intervened when students were off-task or off-topic in both conditions. Although they provided brief instructions at the beginning of each day, it was not necessary that the students followed these instructions. The purpose of this study was to understand the dynamics of the collaborative

| 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. |

**Figure 2.** Argument elements by corresponding Webspiration shapes/arrows and definitions.
argументация процесс with the support of the graph-oriented computer-assisted application in a project-based learning environment. As long as they stayed on track, the researchers did not force the students to follow the instructions. For example, some teams started to argue about counterarguments during the second day and the researchers did not force them to focus only on the position, reason, and evidence. On the third day, the students also had a field trip to an ethanol (biomass) plant.

On the fourth day, the student teams built their solar car and had a solar car race. In the building process, the students were engaged in hands-on experiences (active construction) with their team members under the guidance of the researchers. On the same day, the students visited a wind turbines farm.

The researchers videotaped the classroom interaction among the students with a digital camcorder, including verbal collaborative argumentation in each team and the students’ interactions on Webspiration. The researchers also videotaped and conducted observation of the students’ participation in various activities in the summer camp. The students were required to fill out a survey on the fourth day. The survey asked what activities they liked, what they learned, and what aspect of the summer camp could be improved.

Data Analysis
We conducted the analysis using two coders at two levels. We followed the coding method outlined by Saldaña (2015) for qualitative inquiry, which prescribes a cyclical model that moves from codes to categories and, eventually, themes. In his method, the first level involves two cycles. Methods in the first-cycle coding involved a more direct description of the data. For example, when we analyzed the observation data, we found that all students actively participated in conducting research. The exit survey data also suggested that all students learned and liked the research activities. We used data-driven codes and assigned a descriptive code, AP-RES (actively participated in conducting research), to all data sources that reflect the same phenomenon. We used the same approach and developed a list of codes (e.g., AP-FT-actively participated in field trips, AP-SCB-actively participated in solar car building, AP-SCR-actively participated in solar car races, LAE-learned the importance of alternative energy) to code the observation data of the students’ participation in various activities in the summer camp and the exit survey data.

At the second cycle, we followed Krajcik and Blumenfeld (2006) conceptualization of project-based learning and focused our analysis on using categories of situated learning and active construction. For example, we aggregated all data sources that were assigned codes that indicated how actively the students participated in field trips and built and raced the solar cars, and we labeled them with second-cycle category code, AC, for active construction. We also aggregated all data sources assigned the code that indicate how the students engaged in and/or explored real-world problems (alternative energies) by participating in research activities and labeled them with second-cycle category code, situated learning. At the second level, after drawing from the tentative conclusions about the patterns, we continued to examine the relationships between the patterns and develop themes.

We followed the frameworks suggested by a number of studies (e.g., Hamza & Wickman, 2013; Kelly & Crawford, 1996) to analyze the observation data of the students’ verbal collaborative argumentation in each team and the students’ interactions on Webspiration. To help explain our coding process, we selected a forty-minute episode that involved students’ use of Webspiration to support their verbal collaborative argumentation. Table 1 shows examples from five speakers (Jacob, Alan, Jamie, Henry, and Eric) arguing using Webspiration along with the graph-oriented computer-assisted application’s action, the nonverbal actions of three speakers, and the initial researcher-assigned codes for 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.

After assigning the initial codes, we continued to examine whether the computer-assisted application’s action and code for argumentation skills were associated. We identified patterns that a number of functions of the computer application were associated with types of affordance in the argumentation process as indicated in Table 2. We identified four functions of the computer-assisted application—acting as an ally, exhibiting, helping to construct argumentation, and eliciting—and we also identified the type of affordance with which each function was associated. The description below indicates how each function relates to type of affordance in the argumentation process.
Table 1
*A Transcript of Three Students Working Together with Webspiration and Corresponding Computer’s Action, Nonverbal Action of Three Speakers, and the Researcher-assigned Codes*

| Students’ Argumentation | Computer’s Action | Nonverbal Action | Codes |
|-------------------------|-------------------|------------------|-------|
| Eric: What is our reason? | Shows two light bulbs that represent wind power and solar power. | Starting working in Webspiration. | Discussing a reason. |
| Henry: The conversion efficiency of wind is very high. | Allows students to use different shapes to represent a reason or evidence. | Inserting a position, reason, or evidence in Webspiration. | Demonstrating a position, reason or evidence. |
| Jacob: The output efficiency of converting wind into energy is 20%-40%. | Allow students to use different shapes to represent a reason or evidence. | Inserting a position, reason, or evidence in Webspiration. | Demonstrating a position, reason, or evidence. |
| Henry: Which one is more expensive, solar panel or wind turbine? | Shows two light bulbs that represent two forms of alternative energy. | Starting working in Webspiration. | Generating a counterargument/counterarguments. |
| Jamie: The solar panel is more expensive. | Allows students to use a shape to represent a counterargument. | Inserting a counterargument in Webspiration. | Demonstrating a counterargument/counterarguments. |
| Eric: Will solar panel produce pollution? | Allows students to use a shape to represent a counterargument. | Inserting a counterargument in Webspiration. | Demonstrating a counterargument/counterarguments. |
| Alan: We only need regular mental materials for making wind turbine, not heavy metal materials. Wind energy is mainly depending on the moving of the wind turbines. They will not use high tech products, such as Tin and Germanium. | Shows reasons and evidence that support their position (wind). | Looking at a position, reason, and evidence in Webspiration. | Discussing how geothermal is formed. |
| Eric: Oh, we are using simple materials. They (solar panel) is using complicated materials. | Shows reasons and evidence that support their position (wind). | Looking at a position, reason, and evidence in Webspiration. | Discussing how geothermal is formed. |
| Eric: What did they say? | Shows the team number next to the light bulb that represents a position—solar. | Looking at the light bulb in Webspiration. | Reading other team’s position, reason and evidence. |
| Eric: What should we do now? | Shows the reason, evidence, counterargument/rebuttals of wind and solar. | | Summarizing progress. |
| Alan: We have four shapes. They also have their four shapes. It is their turn. Let’s wait. | Shows the reason, evidence, counterargument/rebuttals of wind and solar. | | Summarizing progress. |
Table 2

| Students’ Argumentation                                                                 | Computer’s Action | Nonverbal Action |
|----------------------------------------------------------------------------------------|-------------------|------------------|
| Eric: What is our reason?                                                               | Exhibiting        | Reading          |
| Henry: The conversion efficiency of wind is very high.                                  | Constructing      | Demonstrating    |
| Jacob: The output efficiency of converting wind into energy is 20%–40%.                 | Constructing      | Demonstrating    |
| Henry: Which one is more expensive, solar panel or wind turbine?                        | Acting as ally    | Claiming         |
| Jamie: The solar panel is more expensive.                                               | Constructing      | Demonstrating    |
| Eric: Will solar panel produce pollution?                                               | Constructing      | Demonstrating    |
| Alan: We only need regular mental materials for making wind turbine, not heavy metal materials. Wind energy is mainly depending on the moving of the wind turbines. They will not use high tech products, such as Tin and Germanium. | Exhibiting        | Reading          |
| Eric: Oh, we are using simple materials. They (solar panel) is using complicated materials. | Eliciting         | Responding       |
| Eric: What did they say?                                                                | Eliciting         | Responding       |
| Eric: What should we do now?                                                            | Exhibiting        | Regulating       |
| Alan: We have four shapes. They also have their four shapes. It is their turn. Let’s wait. | Exhibiting        | Regulating       |

First, when acting as an ally, the application was used by students to support their efforts to make a case. For example, students on the wind team claimed a counterargument against solar to make their case. Second, the application was an external representation that exhibited their argumentation process. Students could make sense of the process by reading the external representation. For example, the students read reasons and evidence provided either by their team (wind) or the other team (solar). The external representation also allowed for consistently monitoring and articulating the learning process, which could be referred to as regulating metacognition. For example, the students looked at the application and summarized their argumentation process. Third, the application helped students construct their argumentation. For example, the students demonstrated their position, reasons, or evidence in Webspirations. Fourth, the application elicited student responses. For example, looking at the external representation of their position, the students responded by providing more reasons and evidence to support their position.

There were two coders who had expertise both in project-based learning and argumentation skills. For each step described above, both coders randomly selected one team and coded a team’s argumentation process independently before they coded all teams’ process. The initial interrater reliability was 80%. The raters then discussed discrepancies. After coming to consensus, all researcher continued to code all teams’ argumentation process.

To better understand the collaborative argumentation process in each team, we assigned a number to each type of affordance (1 = demonstrating, 2 = reading, 3 = responding, 4 = claiming, 5 = regulating) and calculated the percentage of each affordance in each team. To facilitate comparison across teams, the researchers combined the percentage of 1, 2, and 3 as indicated in Table 3 because those affordances
Table 3
Percentage of Each Affordance in the Scientific Argumentation Supported by Webspiration

| Affordance                          | Pair 1       | Pair 2       | Pair 3       | Pair 4       | Pair 5       |
|-------------------------------------|--------------|--------------|--------------|--------------|--------------|
| 1-demonstrating                     | 1 + 2 + 3- 68% | 1 + 2 + 3-60% | 1 + 2 + 3-39% | 1 + 2 + 3-65% | 1 + 2 + 3-58% |
| 2-reading                           | 4-19%        | 4-29%        | 4-29%        | 4-3%         | 4-14%        |
| 3-responding                        | 5-13%        | 5-11%        | 5-32%        | 5-32%        | 5-28%        |
| 4-claiming                          |              |              |              |              |              |
| 5-regulating metacognition          |              |              |              |              |              |
| Team                                | 2            | 4            | 6            | 8            | 10           |
| Gender                              | 4 boys       | 4 boys       | 4 girls      | 4 boys       | 5 boys       |
| Age                                 | 11           | 9-11         | 12           | 12-13        | 12-14        |
| Number of US and Taiwanese students | 1/3          | 1/3          | 2/2          | 2/3          | 3/1          |
| Affordance1-demonstrating           | 1 + 2 + 3-60% | 1 + 2 + 3-62% | 1 + 2 + 3-34% | 1 + 2 + 3-62% | 1 + 2 + 3-57% |
| 2-reading                           | 4-43%        | 4-38%        | 4-30%        | 4-12%        | 4-4%         |
| 3-responding                        | 5-17%        | 5-0%         | 5-36%        | 5-26%        | 5-39%        |
| 4-claiming                          |              |              |              |              |              |
| 5-regulating metacognition          |              |              |              |              |              |
represented how each team was involved in the early stages of scientific argumentation, such as providing a position, reasons, and evidence. The analysis focused on how each team was engaged in different phases in the scientific argumentation with the support of a cognitive tool.

Findings and Discussion

Three themes emerged from our analysis of data related to young adolescents’ learning experiences in various activities in a summer camp: active construction of understanding, engagement and acquisition of knowledge, and social interaction. We also noted patterns of group dynamics in our observations.

Active Construction of Understanding

Regardless of cultural background, age, or gender, all students actively constructed their understanding of alternative energies by participating in all hands-on activities such as conducting research of different types of alternative energies as well as building and racing their solar cars. The survey data suggested that all students enjoyed group work and learned how to conduct research about alternative energy. For example, a 10-year-old Taiwanese student stated that he “improved his English and science knowledge” by participating in the research process. The survey data also showed that all students enjoyed building and racing their solar cars. An 11-year-old American student commented that she enjoyed the solar car building process, but she wished the camp would be longer because their team needed more time to build and refine the solar car. Additionally, an 11-year-old Taiwanese student commented that he learned “how to use knowledge to build a solar car” by actually building a solar car. As suggested by Krajcik and Blumenfeld (2006), the use of active construction methods shows promise in supporting students’ learning science. Consistent with the findings of previous research (Derevenskaia, 2014; Yalcin, 2016), this study found that the use of active construction methods allowed the students to learn the concept of alternative energies more effectively and deeply.

However, the study showed that the students faced a number of challenges in the active construction process. The observations showed that while they actively participated in the research activity, the team comprised of four 10- to 11-year-old girls and the team comprised of four 10-year-old boys requested more information from the camp instructors. The camp instructors had to walk them through the research steps and show them how to synthesize the findings from the materials. Piaget (1972) posited that children progress through four stages of cognitive development. At the sensorimotor stage (birth to 2 years old), the infant builds an understanding of himself or herself and reality through interactions with the environment. At the preoperational stage (ages 2 to 4), the child is not yet able to conceptualize abstractly and needs concrete physical situations. At the concrete operations stage (ages 7 to 10), the child begins to think abstractly and conceptualize, creating logical structures that explain his or her physical experiences. Young adolescents ages 10 to 15 should reach the fourth stage of cognitive development, the formal optional stage, and be able to logically use symbols related to abstract concepts. They should be able to think about multiple variables in systematic ways, formulate hypotheses, and consider possibilities. They should also be able to comprehend abstract relationships and concepts. However, the observation showed that these two teams might still be at the third stage of cognitive development, the concrete operational stage. They could not think abstractly and were not able to synthesize the findings from the research materials; thus, they demanded more support from the camp instructors.

The camp instructors walked all students through the steps of building a solar car. The students could determine where they installed the motor for driving the gears, the angle of the solar panel, and the distance of the four wheels. However, our observations indicated that when building the solar car, the Taiwanese students tended to ask for camp instructors’ guidance and reassurance about the design of the solar car more frequently than the American students. These Taiwanese students were used to learning through lectures and demonstrations and rarely had experience engaging in student-centered, collaborative, small group learning in science classrooms. Although the camp instructors introduced project-based learning to the students during the first day of the camp, the frequent requests for reassurance suggest that the Taiwanese students may have felt their typical communication style was being challenged (Gwee, 2008; Zhou & Shi, 2015) and needed to learn how to navigate the novice learning environment. To respond to the potential challenge with Taiwanese students, we recruited local teachers to provide in-time support to the students when the camp instructors assisted other students.

Engagement and Acquisition of Knowledge

Regardless of cultural background, age, or gender, all students were engaged in the discussion and
explore the engagement of a real-world meaningful problem: “Which alternative energy is the best?” The students were guided to research the use of alternative energies in different countries. The camp also provided opportunities for them to visit an ethanol plant and a wind turbine farm in the area. At the end of the camp, the students reflected on which alternative energy the American or Taiwanese governments should fund and why, similar to activities in which adult professionals would engage. In the survey, a number of American and Taiwanese students indicated they learned about alternative energies in their science classes. They were able to connect to their prior knowledge and explore the potential for the different types of alternative energies where they live. Research (Brown et al., 1989; Sadler, 2009; Tidemand & Nielsen, 2017) has documented that students who engage with socio-scientific issues can acquire some of the complex competences and skills typically related to scientific literacy. In this summer camp, through exploring the socio-scientific issue of alternative energies, the students acquired knowledge about alternative energies in a meaning context and extended their knowledge from formal science learning contexts, which prepares them to participate in society in the context of science-related social issues.

**Social Interaction**

Regardless of cultural background, age, or gender, all students engaged in the social interactions with the support of a cognitive tool. In this summer camp, the students formed 10 teams. The camp instructors paired teams to engage in scientific argumentation about “Which alternative energy is the best?” with the support of a graph-oriented computer-assisted application. The survey data indicated that all students enjoyed the activities. A number of Taiwanese and American students shared they learned how to argue like a scientist. A 10-year-old Taiwanese student felt “he learned about alternative energies in depth” through engaging in scientific argumentation with peers with the support of the computer-assisted application. Consistent with the findings of previous research (Hsu et al., 2016), this study found that the students were able to work with others via social interaction and the computer-assisted application, serving as a cognitive tool, augmented the social interaction by making the students’ thoughts visible to their peers in this summer camp.

**Patterns of Group Dynamics**

Analysis of the observation reveals patterns in three different group dynamics, as indicated in Table 3. Team five and team six in pair three (which had an equal number of American and Taiwanese students and were 11- to 12-year-old girls) had a good balance among the different components of scientific argumentation with the support of the computer-assisted application. In team five, 39% of their argumentation involved providing reasons and evidence, 29% involved counterargument and rebuttal, and 32% involved regulating metacognition. In team six, 34% of their argumentation involved providing reasons and evidence, 30% involved counterargument and rebuttal, and 36% involved regulating metacognition. Previous studies (Asterhan et al., 2012; Ma & Yuen, 2011) reported that female students demonstrate higher participation than males in computer-assisted collaborative activities. Female teams demonstrated balanced participation in the construction of argumentation in the computer-assisted application. Compared to homogeneous all-boy groups, homogeneous all-girl groups had a higher degree of participation and scored higher on aspects of collaborative argumentative quality. This study showed that this grouping dynamic can result in a good balance among different components of scientific argumentation and may benefit 11- or 12-year-old students and students who have different levels of English proficiency.

On contrary, among the four teams in pair one and pair two with ages of 10 and 11, at least 60% of their argumentation involved providing reasons and evidence. Their counterargument and rebuttal among four teams ranged from 11% to 43%, but metacognition regulating ranged only from 0% to 17%. Among the four teams in pair four and pair five with ages ranging from 11 to 14, at least 60% of their argumentation involved providing reasons and evidence. However, the counterargument and rebuttal among four teams ranged from 3% to 14%, while their metacognition regulation ranged from 26% to 39%. Although previous studies showed that young adolescents tend to face challenges providing counterarguments and rebuttals (Crowell & Kuhn, 2014), this study showed that the computer-assisted application seemed effective in affording the student teams the ability to engage in counterargument and rebuttal. Although it appears that teams of all grouping types demonstrated metacognition regulation skills, the skills showed in different degrees in different types of groupings. The teams with younger students tended to show a lower level of metacognition regulation than the teams with older students. While age might be an important factor
resulting in different degrees of metacognition regulation, the Taiwanese students outnumbered American students in seven of the eight teams. In their survey, a few American students pointed out they were the only American student on the team and hoped there would be more American students.

We observed that English was a second language for the Taiwanese students, and the students in pair one and pair two were younger and did not have as high a level of English proficiency as the students in pairs four and five. For example, at the beginning of activity, the teams of older students tended to look at computer-assisted application 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 said, “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 to “stick to scientific facts not opinion.” When they wrapped up the activity, the teams of older students tended to summarize their argumentation process and looked for grammatical errors on the argumentation map in the computer-assisted application. These behaviors could be considered metacognition regulation, such as referring to notes and resources and delegating tasks to team members for collaborating on and summarizing the argumentation.

In contrast, the teams of younger students in pairs one and two, particularly the students from Taiwan, tended to look at the computer-assisted application and each other and said in Chinese “What do we do now?” and “I have no idea what to do.” The instructors, who spoke both English and Chinese, had to guide them in learning how to share the workload and how to communicate with the American team member during the collaborative argumentation process. Additionally, during construction of the argumentation map, the instructors had to consistently remind them to refer to the materials.

This lack of metacognition regulation could be attributed to both age and their limited English proficiency (Hsu et al., 2017). This finding parallels Weil et al. (2013), who investigated the development of metacognitive ability from adolescence into adulthood using a psychophysical procedure. They found an interaction between age and metacognitive ability, in that metacognitive ability increased with age during adolescence. Similarly, in their three-year study, Van Der Stel and Veenman (2014) found growth in both the frequency and quality of metacognitive development among students from age 13 to age 14. However, they also indicated that not all components of metacognitive skills develop at the same pace for adolescents. In the current study, the students in pairs one and two were 10 to 11 years old, which may explain the lack of evidence of metacognition regulation in the process.

As revealed by this study, the Taiwanese students had varying levels of proficiency in English and tended to keep silent, which presented a challenge in the learning process. As in previous studies (e.g., Frambah et al., 2014; Gwee, 2008), the Asian students’ proficiency in English presented difficulties for implementing project-based learning. Additionally, because the Taiwanese students outnumbered the American students in seven of the eight teams, the Taiwanese students tended to engage their discussion in Chinese first and translated their conclusion to their American team member, which presented another challenge in the learning process. That also may explain why a few American students pointed out they were the only the American student in their team and felt isolated due to the language barriers.

Overall, the summer camp incorporated four principles of project-based learning (active construction, situated learning, social interaction, and cognitive tool), which shows the potential for engaging students in science. The majority of the students stated that they “learned so much and had fun at the same time.” They also felt amazed that they learned so much from a summer camp. None of the American students had traveled to Asia, and they pointed out that they had fun interacting with the students from Taiwan. As indicated in previous research (Bhattacharyya et al., 2011; Urness & Manley, 2013; Vossoughi & Bevan, 2014), the deeply intellectual aspects of play inherent in summer camps could help expand relationships involving students’ capabilities in science.

Implications and Conclusion

In a summer camp, active construction is an important design feature. However, informal science educators may need to provide more research time to students because exploration of new ideas takes time. For the students who have not reached the formal operational stage and might have trouble with
research steps, informal science educators need to provide more support, such as dedicated camp instructors for younger students. To meet the needs of a diverse student population, it is also important to provide strategies regarding how to think independently and how to collaborate and communicate with students of different cultures. Further research is needed to explore strategies for engaging Asian students or students who rarely experience project-based learning in informal science learning contexts. The study also suggests that another design feature of situated learning in a summer camp can help students extend the knowledge learned in formal science learning contexts. The integration of socio-scientific issues can be one of the strategies.

It is also helpful to incorporate social interaction and a cognitive tool into a summer camp. In particular, social interaction may involve grouping strategies. When grouping students, it is important to consider students’ demographics such as age, gender, or cultural background, including English proficiency. While the computer-assisted application is effective in supporting students’ development of scientific argumentation, for younger students such as 10- or 11-year-olds and English learners, the informal science educators should provide more guidance in regulating metacognition-related tasks. Additionally, due to advancements in technology, the cross-cultural application of project-based learning has gained popularity in Asian classrooms. To ensure that Asian students are engaged in and are able to capitalize on the benefits of project-based learning, it is necessary to provide training on how to engage in the process and what skills and English proficiency they need to prepare (Frambach et al., 2014; Gwee, 2008).

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