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DESIGNING AN ONLINE GRAPH-ORIENTED COLLABORATIVE ARGUMENTATION TOOL FOR MIDDLE SCHOOL STUDENTS: A FACULTY EXPERT'S PERSPECTIVE

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The objective of this design case is to describe a cross-cultural, online graph-oriented collaborative argumentation tool for middle school students from a faculty expert's perspective, and discuss the processes that were instrumental in creating the tool. Supported by the professional staff in the Digital Convergence Lab (DCL) at Northern Illinois University, a student team was involved in the design process of such a tool. The team designed two versions of graphic icons to represent the essential elements of argumentation skills. The first version of icon designs used human figures and symbols to represent two groups, five argumentation elements, and one icon for teacher input. After middle school students, in the United States and Taiwan, experienced the icon designs, the design team refined them to be gender and culturally neutral. The design team also modified the design of the user interface throughout the project.

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CONTEXT

Middle school is a critical age in which argumentation skills develop (Kuhn, Wang, & Li, 2010). The tool we designed aimed at supporting the development of middle school students' argumentation skills to make claims from evidence, as advocated by the Next Generation Science Standards (National Research Council, 2012). A number of researchers (e.g., Kuhn, 1993) have defined essential elements of argumentation: position, reason, evidence, counterargument, and rebuttal. *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. *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. Collaborative argumentation is a means of arriving at an agreed-upon position between members of a group (Andriessen, 2006; Jonassen & Kim, 2010). Although collaborative argumentation is not limited to science, this type of argumentation is practiced when scientists build upon and sometimes refute one another's theories and empirical research to arrive at scientific conclusions. For example, scientists could argue about different types of alternative energy, and come to a consensus about the appropriate energies in different areas. The concept of science as an argument, and the view that engaging in scientific argumentation should play a key role in science education, has become widely advocated in science education reforms in the United States (National Research

Council, 2012) and Asian countries such as Taiwan (Ministry of Education in Taiwan, 2003).

In the past few years, the "Argue like a Scientist with Technology" (ALAST) research team at Northern Illinois University has conducted studies to examine ways to develop students' development of argumentation skills in a graph-oriented computer-assisted project-based argumentation curriculum. One of the studies (Hsu, Van Dyke, Chen, & Smith, 2015) investigated how the U.S. and Taiwanese students were engaged in collaborative argumentation with the support of an online graph-oriented program and how this intervention led to their development of science argumentation skills and science knowledge. The research team reviewed the literature (Scheuer, Loll, Pinkwart, & McLaren, 2010; Suthers, Vatrapu, Medina, Joseph, & Dwyer, 2008) and investigated several online graph-oriented tools. Although the graph-oriented tools are numerous (e.g., Digalo, Belvedere, Araucaria) and each of them has a different way of constructing argumentation maps, there are a number of common features across these tools. For example, contributions are displayed as boxes or nodes that represent argument components, such as claims. The arrows represent the relation between the argument components (e.g., supports or refutes). The different components of arguments and relations can be easily distinguished via their visual appearance. Most tools in the literature were outdated (e.g., CoFFEE) or were designed for college students (e.g., Belvedere). The research team used three criteria to select a potential tool with a capability of (a) supporting argumentation and expressiveness, (b) allowing online synchronous/asynchronous collaboration, and (c) working on PC and Mac platforms. The research team selected a proprietary concept mapping tool as the basis of the graph-oriented tool in their study because it had the features and criteria described earlier.

Since this study, the faculty expert (the first author and the principle investigator of the research team) has received feedback from science teachers and student participants and proposed the design of a custom online graph-oriented collaborative argumentation tool specifically for middle school students in both countries instead of customizing the proprietary concept mapping tool. The faculty expert collaborated with the Digital Convergence Lab (DCL) at Northern Illinois University (NIU) and formed an experiential learning team. The purpose of forming this team was to bring together a group of interdisciplinary talented graduate and undergraduate students to solve real problems. The DCL professional staff supported the student team.

Experiential learning projects at the DCL are typically completed in two academic semesters. Students are recruited, interviewed, and selected by the lab staff based on the needs of the project. In the first semester, students become part of a design team, and in the second semester, students become part of a development team. The current paper focuses on the experience of the design team in the first semester.

Based on the design project described by the faculty expert (first author), the DCL staff anticipated the need for computer programmers and students familiar with the notions of argumentation and communication as well as concept artists and students who would focus on learning. The students on the design team were interviewed and screened from a larger pool of candidates who applied to become part of the Experiential Learning project. The staff specifically looked for students with expertise in programming, instructional design, learning and communication theories, or graphical design. The staff also looked for students with good oral and written communication skills, collaborative working experience, and an interest in this project. The final design team consisted of four NIU students and three DCL professional staff members. The student members consisted of two students from the ETRA (Educational Technology, Research and Assessment) department, one from Computer Science, and one from Communication Studies. The staff members consisted of a coach, an assistant coach, and a graphic designer.

DESIGN OVER TIME

The design team was formed at the beginning of the semester and met regularly. Initial design meetings focused on establishing project expectations from the team members as well as discussing the faculty expert's intended outcome. The intended outcome was to design an online cross-cultural, graph-oriented collaborative argumentation tool for middle school students (aged 10-15) to develop their argumentation skills through discussing topics in science.

During the semester, the DCL coach led the discussion of the design of argumentation elements and interface design. All design decisions went through the design team members, the coach/assistant coach, the users, and the faculty expert.

Argumentation Elements and Interface Design

The team's next step was to clarify user types, roles, permissions, the user environments, and the design of the argumentation elements. During the early sessions, a need for agreed-upon definitions of project terms and semantics arose (see Table 1). These definitions provided holistic guidance for the type and design of the argumentation elements and wireframes for the layout of the online argumentation tool.

The initial conceptual design for the format of argumentation included a traditional concept map order, involving the drag-and-drop function. The design team decided to focus on traditional concept mapping because most middle school students are familiar with that format. The concept

map order shows hierarchical relationship between a base argumentation element (e.g., reason) and argumentation element that refers to it (e.g., counterargument). The relationship could be either *support or refute*. There were a lot of back and forth discussions among the design team, the faculty expert, and the users when designing the argumentation elements and the layout.

PROJECT TERMS
CLIENT: faculty expert.
DESIGNER: person responsible for the creation of the design document and prototypes for the tool.
DEFINITION OF DESIGN ELEMENTS
CONTAINERS: digital objects that represent argumentation elements and connect the argumentation process as a whole.
ICONS: graphic identifiers. These will attach to the containers for identification.

TABLE 1. Sample project terms and semantics.

The first design tasks included the creation of argumentation element objects (called *containers*), icons, and relationship signifiers (arrows). The term *container* stems from the function of the object—which is to display quick information externally (e.g., a title or group ownership) and to house internally explanatory items such as text, images, files, and links that can expand when the container is double-clicked. The container designs in their initial phase were very colorful rectangles that displayed a title, a group icon, and an argumentation icon (e.g., a check mark for a "reason" container; see Figure 1). These containers could be dragged from a dock on the user interface and placed on the workspace. From here, users could select a title, add the internal explanatory text, add content, and indicate the type of relation this container would have to another (supports/refutes). The next step was to create graphical icons with strong intrinsic meanings to differentiate the container types.

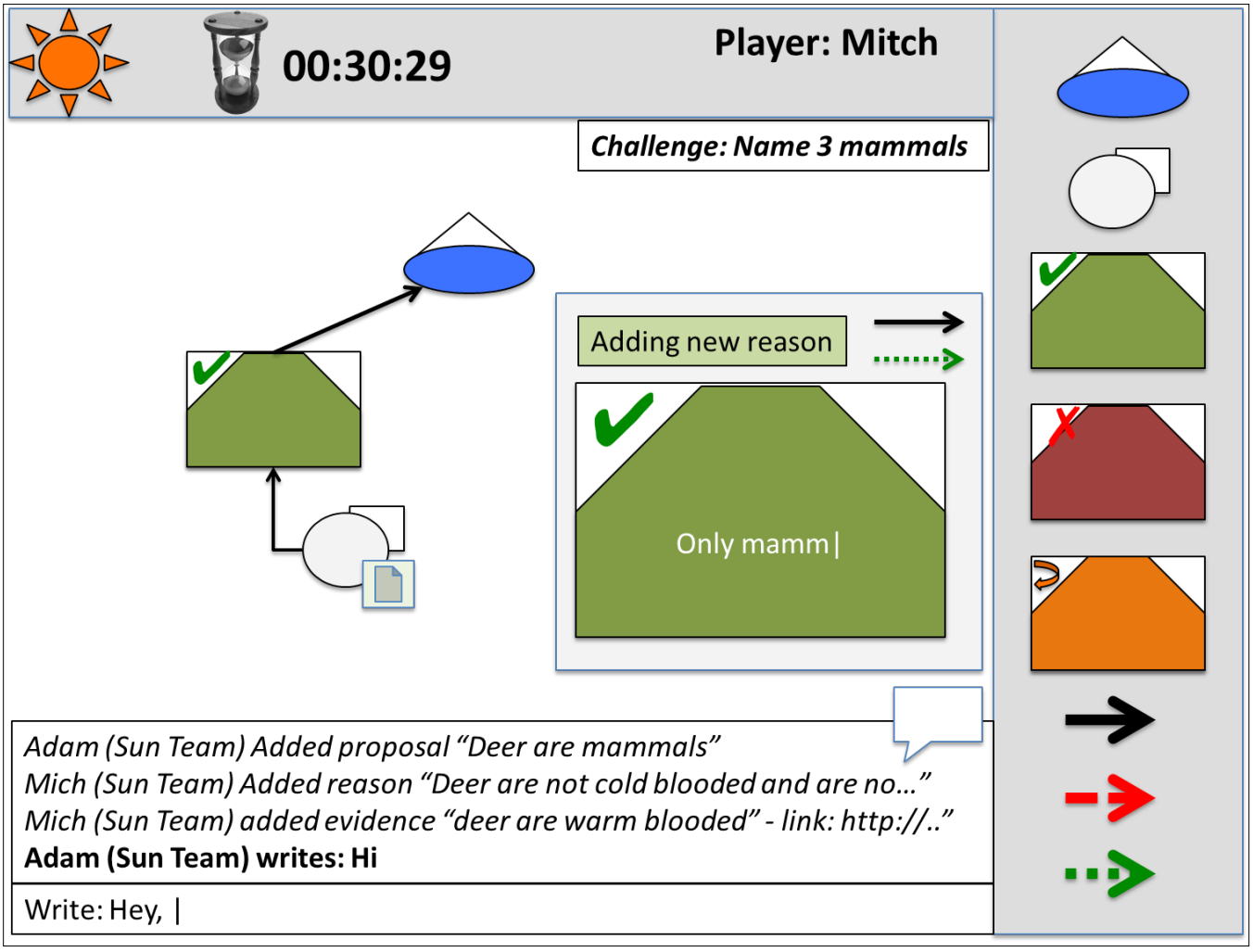

FIGURE 1. Early interface design. ©2014 by the Board of Trustees of Northern Illinois University. Reprinted with permission.

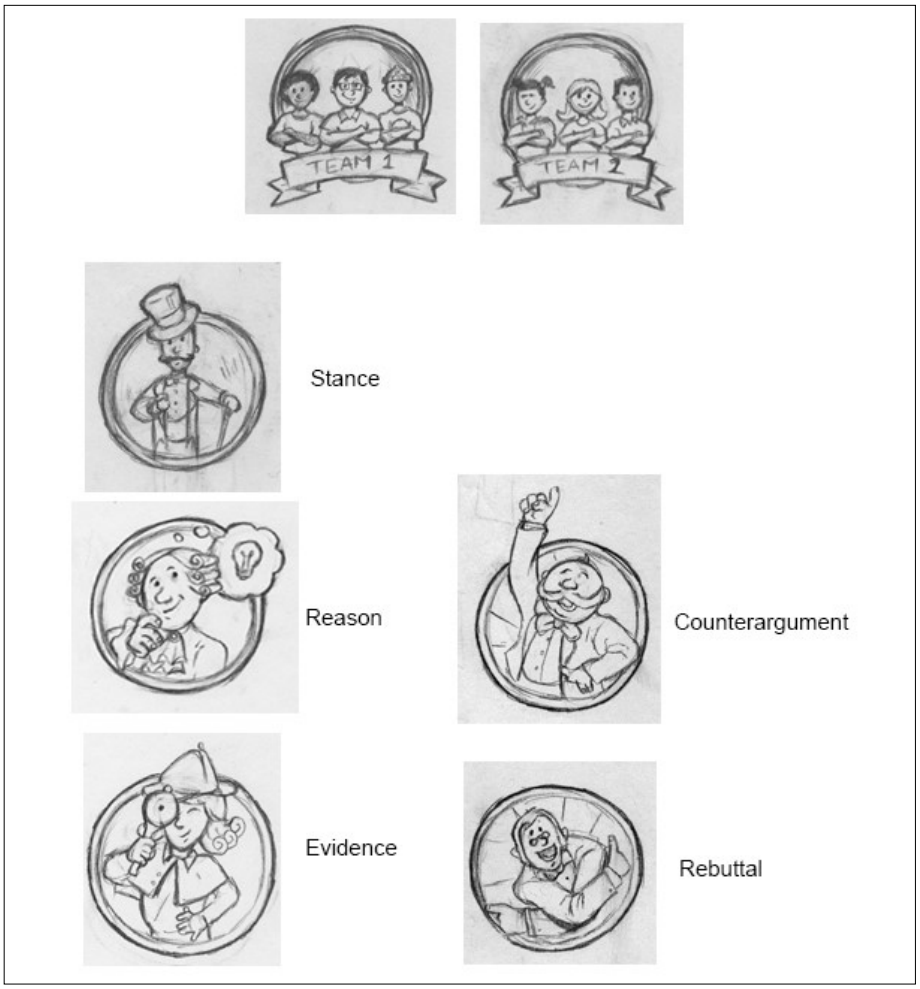

FIGURE 2. Icon designs: First version of the sketch. ©2014 by the Board of Trustees of Northern Illinois University. Reprinted with permission.

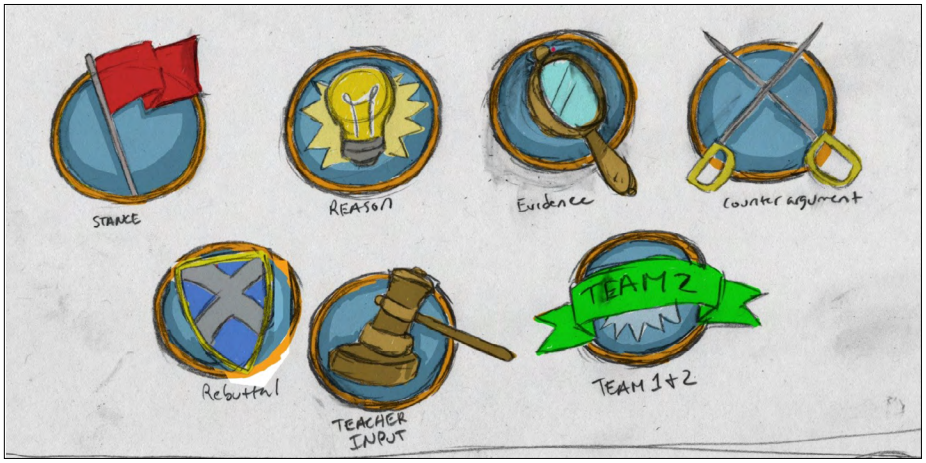

FIGURE 3. Icon designs: Second version of the sketch. ©2014 by the Board of Trustees of Northern Illinois University. Reprinted with permission.

The icon designs had two iterations. The first version of icon designs used human figures and symbols to represent groups and argumentation elements (see Figure 2). Initially, the design team and the faculty expert identified that only human beings are capable of engaging in the high cognitive activity, that is, argumentation and decided to use human figures. It was important to the team to create icons and containers that were accessible and held intrinsic meaning. The team proposed icon designs and sent them to the faculty expert for review. After the faculty expert had shared the icon designs with the students both in the United States and Taiwan (see the Users' Experience section), the Taiwanese students identified a Western-centric theme (Victorian-era characters) and the students in the United States pointed out the visual complexity of the design. As shown In Figure 2, each icon had too many details and looked complex to the students. Additionally, the design team and the faculty expert also identified that the size of icons did not accommodate the complex human figure design. The faculty expert suggested using gender and culturally neutral icons to represent the argumentation elements. The design decisions were not easy because they were based on several different inputs from students as well as endless discussions between the faculty expert and the design team members.

The second version of the icons focused on increased minimalism and creating gender and culture neutral representation. The icons shown in Figure 3 featured symbols that are generic in terms of gender and culture and that also conveyed meaning more universally (e.g., a *flag* for a position, *crossed swords* for a counterargument, *magnifying glass* for evidence, etc.), and so succeeded their predecessors. In addition to the five argumentation icons, one

icon for teacher input and two icons for each group were designed.

Once the new icon designs were accepted, the design team re-evaluated the workspace layout and the drag-and-drop functionality. In these meetings, it was decided to radically simplify the flow of argumentation. Early in the design process, adopting a drag-and-drop model seemed effective. However, as the complexity of the tool grew, the organization of the user-generated content became increasingly chaotic. This, in turn, led to unexpected design problems, especially in cases involving large arguments. To remedy the problem, the design team investigated alternative approaches to handling the interface and the data that users would be submitting. Ultimately, the team abandoned the traditional drag-and-drop functionality of conventional concept mapping. Instead, the team began to adopt a modified hierarchical design to the argumentation process.

The new hierarchical interaction structure focused on a parent-child relationship display for the various argumentation components (containers), as indicated in Figure 4. The team considered this a major design change as it minimized distractions and focused users on specific contingencies without being cognitively overwhelmed by the entirety of the argument (cognitive overload). The new hierarchical structure also minimized the space that large arguments take. In the modified design, a single argumentation element is displayed at the top of the screen (the parent), and then the responses (children) to that element are displayed below it. A "para-level" was also created to denote continued argumentation elements beyond a displayed child—represented by its respective icon's symbol and attached to the child. These "children of the children" act as minimized argumentation elements that expand as the argumentation moves down. The idea was that when users click on a *child* of a *parent*, that child *becomes* the parent (moving to the top of the screen) and the para-level icons expand into the new children.

Design Decisions

The movement to simplify the argumentation tool inspired the team to make radical modifications related to (a) the container and icon designs, (b) the process for structuring and adding argumentation elements, and (c) the design of the user interface. The result of these modifications was an "a-ha" moment for the design team and the faculty expert because everything came together. This all began with the decision to make the containers' color and design universal among the various argumentation elements, and for monochromatic icons to use color alone to clearly differentiate container ownership by a group. The visual effect was a sleeker, more modernistic appearance of the containers (with icons), which created a non-distracting consistency, yet clearly communicated group ownership of the various representations of the argumentation elements (containers).

With the elimination of the drag-and-drop functionality, the process for adding argumentation elements also changed. Within the parent-child format, groups would add new elements through an addition icon (+) on the parent container. Users would then choose which element they want to add, and it would become a new child under that parent on the screen. The process for adding content to the argumentation element container remained mostly the same; however, it was determined that the types of relationships previously represented by distinct line types were no longer necessary within the new format, as the relationships were implicit in the placement of items in the hierarchy. This change also inspired the design of what became the final graphics and icons for the tool. No longer requiring the palette of drag-and-drop options, the icons were retooled to function as simple representatives of the different types of user submitted content (reasons, evidence, counters, etc.).

The argumentation tool's user interface (UI) was designed from the beginning to be a minimalistic workspace that presented various elements and functionality without unnecessary distraction. Figure 4 shows the final interface design. The interface includes (a) a workspace in the middle; (b) an information bar on the top (featuring a timer to assist students in managing their time, group name, player name, topic discussed, and login/out tab); (c) a chat box on the lower left corner; (d) a container dock on the left (showing representatives of the different types of user submitted content); and (e) a development space at the bottom (for future modifications or enhancements such as a tutorial mini-screen). Figure 5 shows the early interface design. The early interface design was derived from the review of the existing concept mapping tools and the discussion between the design team and the faculty expert. With the exception of reconfiguring the spatial arrangement of these elements and users' experiences, the user interface changed very little from its initial conception. With the design decision to switch to a parent-child relationship, the development space was suggested as an area to feature a mini-map of the argumentation tree and act as a location tracker for where the displayed contingency was located in the argument.

USERS' EXPERIENCE OF THE DESIGN

As described earlier, the research team has identified a need to develop an online graph-oriented collaborative argumentation tool specifically for middle school students in Taiwan and the U.S. Therefore, the design team and the faculty expert decided to solicit direct feedback about the icon designs of the argumentation tool from middle school students in those two countries. The faculty expert met with a group of approximately 110 U.S. middle school students (from 6 classes) and 23 Taiwanese middle school students

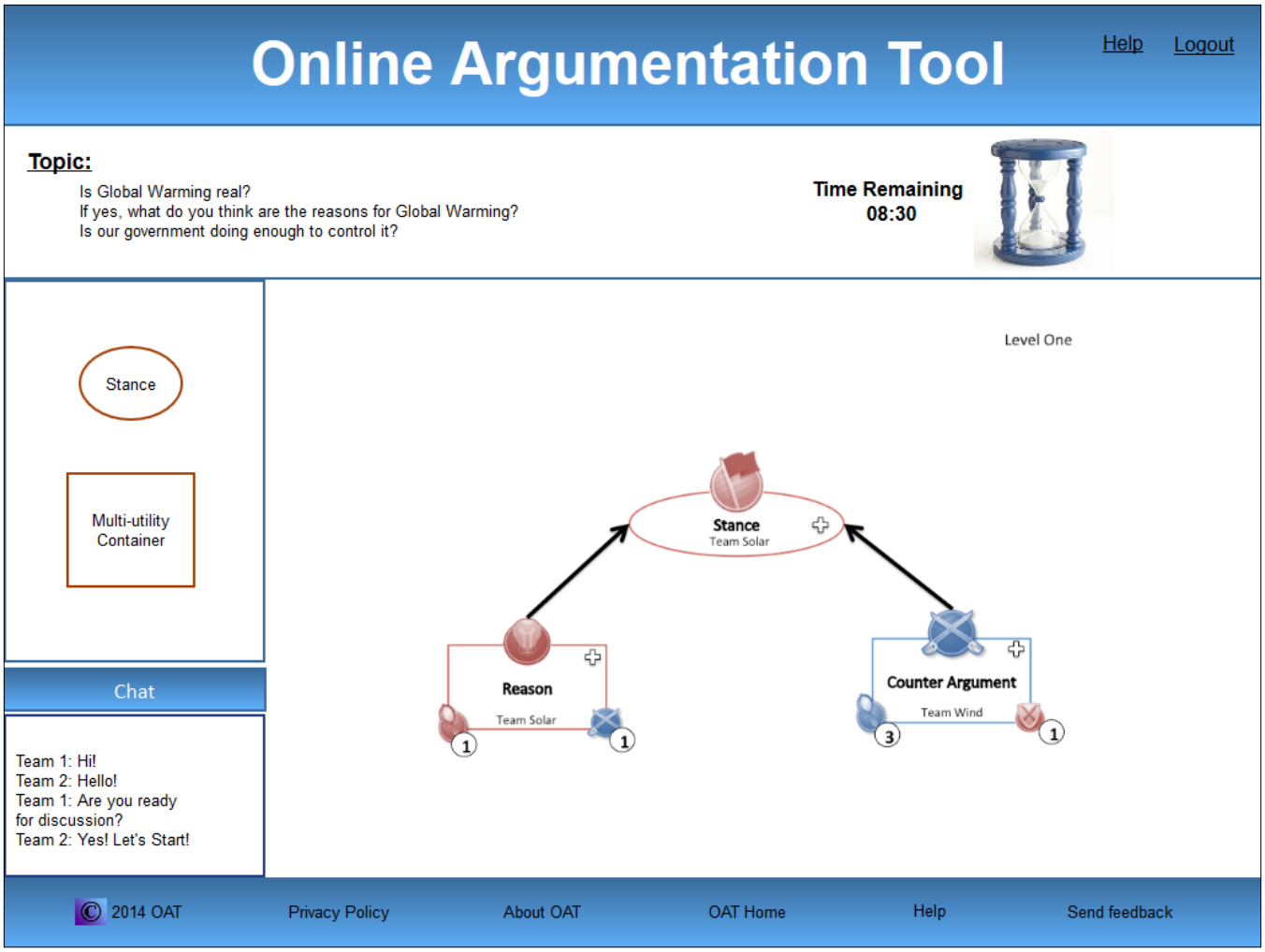

FIGURE 4. Most current interface design. ©2014 by the Board of Trustees of Northern Illinois University. Reprinted with permission.

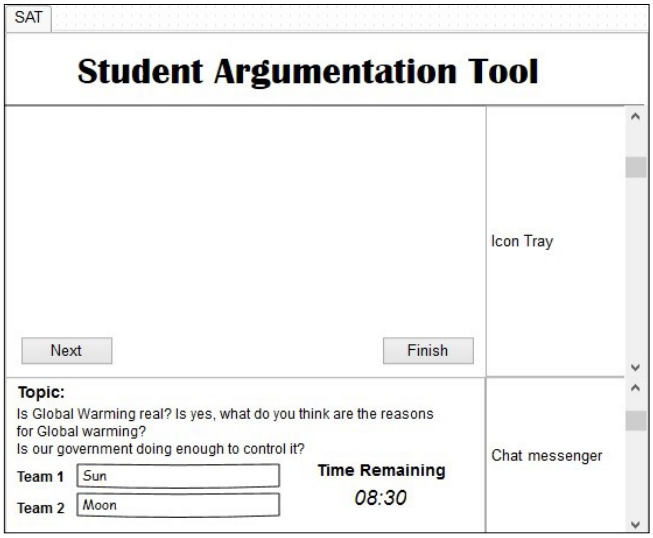

FIGURE 5. Early interface design. ©2014 by the Board of Trustees of Northern Illinois University. Reprinted with permission.

(from 1 class). The faculty expert solicited the students' feedback twice: one in the middle of the semester and the other at the end of the semester. The faculty expert used a number of researchers' recommendations and guidelines (e.g., Chakraborty, Hansen, Denenberg, & Norcio, 2009; Fernandes, 1995; Russo & Boor, 1993) for cross-culture interface design and usability as discussion points with the students. For example, does the icon design make sense in their culture?

In the middle of the semester, the faculty expert demonstrated the icon design of each argumentation skill (Figure 2) on the whiteboard and asked the students to comment on them. The comments were recorded and transcribed for further analysis. The U.S students felt the designs contained too much detail, which they felt might be distracting, and suggested removing the human figures. The Taiwanese students felt that the characters were too Western-centric and the designs might not be effective for them to associate with each argumentation skill.

At the end of the semester, the faculty expert again showed the icon design of each argumentation skill (Figure 3) to the students. The students felt the final icon designs represented each argumentation skill very well. Mark (pseudonym) commented on the use of a flag to represent a position:

> *"I think it makes sense because when you think about flags, it represents certain area. So your position will be what you believe in, so the flag will be where I am taking my stand."*

Kristin (pseudonym) commented on the use of a light bulb to represent a reason:

> *"It is easy to be associated. I guess whenever you think of a light bulb in a TV show settings, it is always when people have a light bulb, it means that they come up with an idea or skim something, it is a reason to support your evidence as an idea."*

Hui-Rui (pseudonym) commented on the use of a magnifying glass to represent a piece of evidence:

> *"It makes sense because magnifying glasses mean you are kind of finding something with them or investigation for testing something."*

Josh (pseudonym) commented on the use of crossed swords to represent a counterargument:

> *"When you think about counterargument, that is, you state you [sic] position, another person will prove what you say is wrong. So it would like to be that you two are fighting or arguing. Sword represents fighting."*

NaNa (pseudonym) commented on the use of a shield to represent a rebuttal:

> *"It makes sense because you prove that your reason is right and you protect yourself with the shield."*

The students felt the group icons were appropriate and provided suggestions:

> *"The use of color is a good way to tell the differences of the groups and identify the groups. It is a simple way to tell which group you are in…. It is a good idea to ask the designers to give you options to choose the color for different group. If the students have the flexibility to choose colors, we will choose red, purple, green, blue, and yellow."*

The only issue that the students in both countries pointed out was with the use of a gavel to represent teacher input. The majority of the students felt that a gavel carries a negative meaning. Jack (pseudonym) said,*"I don't like gavel. It seems like hit something and gets attention, like in the court…. A teacher's input is not necessarily negative or necessarily positive."* The students in both countries brainstormed ideas such as a grade, a check mark, and an apple. The U.S. students indicated that the use of an apple to represent teachers is universal. However, the Taiwanese students were not able to make such a connection in their culture. Based on the comments from the students in both countries, the faculty expert chose a highlighter to represent teacher input because students in both countries could understand what a highlighter means. The students said, *"The highlighter is not good or bad…just draw attention to it. For example, a yellow marker."*

SUMMARY

The objective of this project was to design an online graph-oriented collaborative argumentation tool for middle school students in Taiwan and the United States. Based on the users' feedback from both countries, the design team was involved in constant revisions of the icon designs and the interface design. The final icon design of each argumentation skill accomplished here was done by students and resulted in an icon set accepted by the users in both countries. The design team provided a design document and passed it to the development team for the following semester.

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