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DEVELOPMENT OF 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 was to describe the development of an online graph-oriented tool to support the representation of collaborative argumentation for middle school students from a faculty expert's perspective and discuss the processes that were instrumental in developing the tool. Supported by the professional staff in the Digital Convergence Lab (DCL) at Northern Illinois University, a student team was involved in the development process of such a tool. Based on the design document from the design team, the development team developed a prototype and the faculty expert conducted a series of usability tests with 119 middle school students in the United States. Overall, the results of the usability testing suggested that the prototype is targeted at supporting the representation of scientific argumentation. The student participants also provided suggestions for further improvement of the prototype.

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CONTEXT

Middle school is a critical time for students in which argumentation skills are developed (Kuhn, Wang, & Li, 2010). The tool we designed and developed was aimed at supporting the development of middle school students' argumentation skills and 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 on 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 have become widely advocated in science education reforms in the United States (National Research Council, 2012) and in 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, 2016a) 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 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 out of maintenance due to the completion of grant projects (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 (to be introduced in later sections) in their study because it had the features and criteria described earlier.

Since this study, the faculty expert (the first author and the principal 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 the U.S. and Taiwan 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 to bring together a group of interdisciplinary talented graduate and undergraduate students to solve real problems. The DCL professional staff and faculty expert 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 experience of the design team was published in an earlier issue of the *International Journal of Designs for Learning* (Hsu et al., 2016b). The current paper focuses on the experience of the development team in the second semester and the usability study conducted in the following semester.

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 development 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 work experience, and interest in this project. The final development team consisted of three NIU students, the faculty expert, and one DCL professional staff member. The student members consisted of one student from ETRA, one from Computer Science, and one from Communication Studies. The staff member served as a coach.

DEVELOPMENT OVER TIME

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

During the semester, the DCL coach led the discussion of the development of an argumentation prototype. The team began with reviewing the design document proposed by the team and prioritized design elements in the design document. The top priority tasks included the development of the argumentation interface and the integration of a real-time chatting tool as one important function. The development team researched existing argumentation tools on the market and conducted research on jQuery library and other real time collaboration application programming interfaces (APIs). The development team followed wireframes (see Figure 1) to build the web application described in the design document.

The team developed the web application using HTML5, JavaScript, CSS, MySQL, PHP, and jQuery. As shown in Figure 1, the wireframes have a design element of real-time collaboration in written form, such as online chatting in the lower-left corner, but do not have any design element of real-time collaboration in verbal form. The verbal component refers to any real-time online tool that allows student participants to talk to each other. The faculty expert, after discussion with the development team, incorporated the element of real-time collaboration in verbal form because in previous

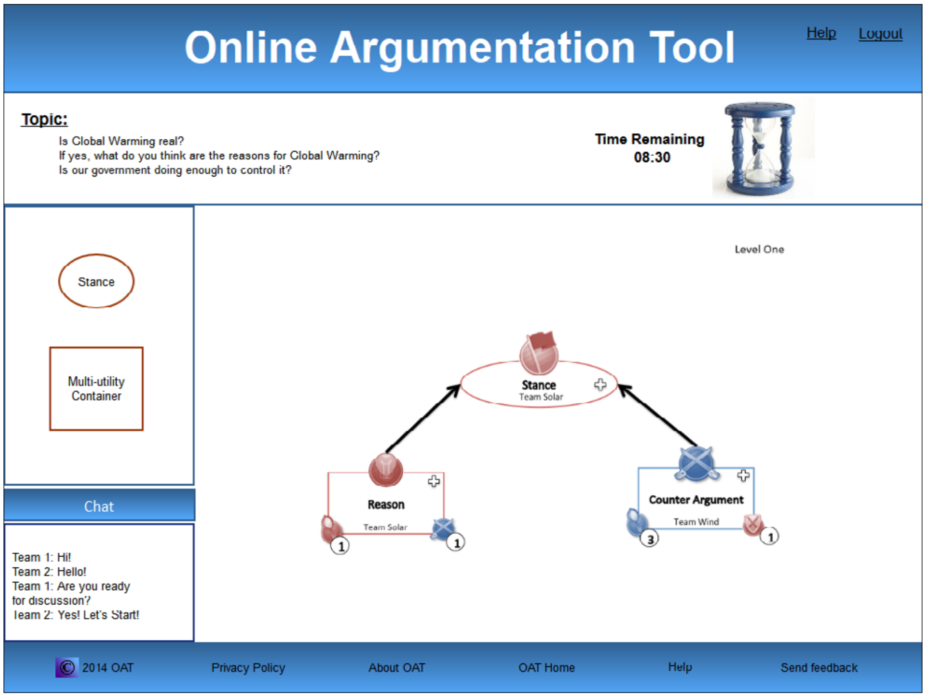


FIGURE 1. Argumentation Page in the First Iteration. Reprinted from Prototype, by P.-S., Hsu, 2014, Illinois: Northern Illinois University. Copyright© 2014 by the Board of Trustees of Northern Illinois University. Reprinted with permission.

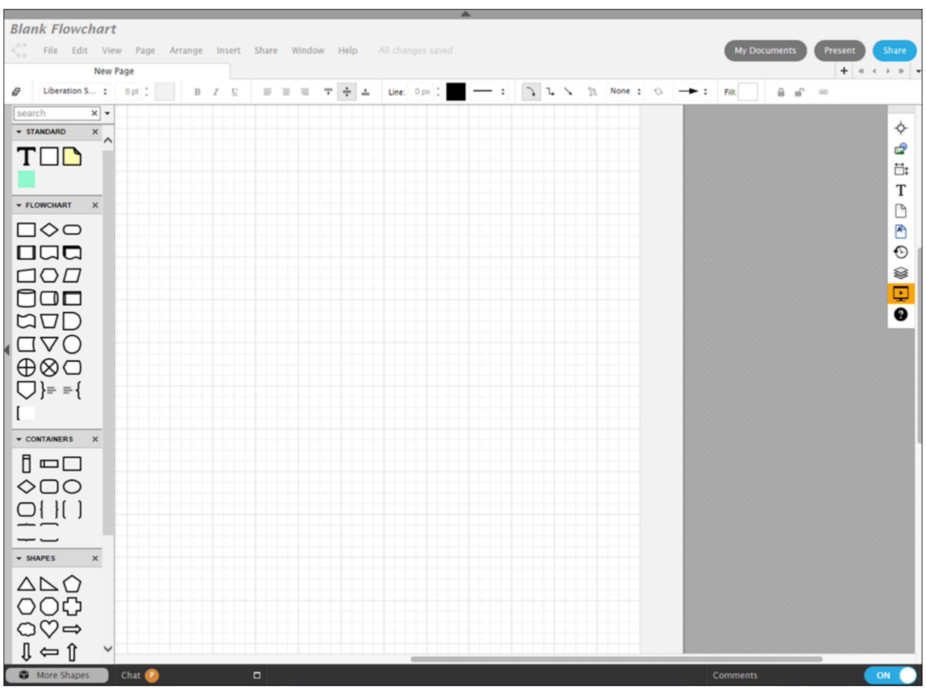


FIGURE 2. Screenshot of Proprietary Tool. Reprinted from Proprietary Tool, by Lucid Software Inc., 2018, Utah: Lucid Software Inc. Copyright© 2018 by Lucid Software Inc. Reprinted with permission.

studies conducted by the faculty expert, argumentation in both written and verbal forms was required. The development team identified TogetherJS, which is a real-time collaboration service from Mozilla, which is JavaScript-based, and is ready to use out of the box with minimal configuration for verbal communication.

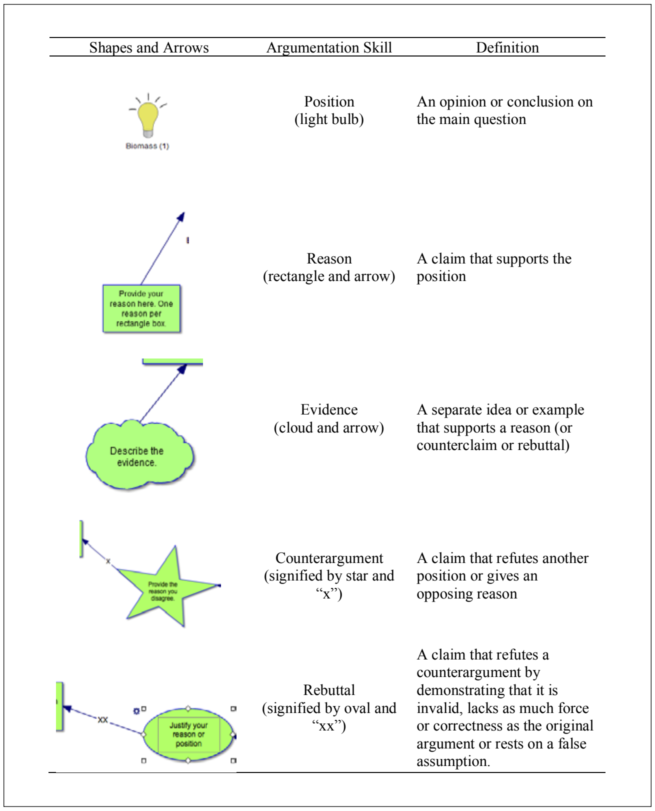
By the end of the semester, in terms of interface development in the prototype, the development team completed the login screen, teacher registration page, and argumentation page (see Figure 1) as well as the online chatting feature. However, due to time constraints and technical difficulties, the team was not able to complete the administration page or the Auto Save and Progress Tracking features. Additionally, they were not able to build the parent/child function into the argumentation page.

The faculty expert had a discussion with the development team about the progress and reflected on the design process. The team pointed out that there were too few team members, and the development of software programs required technical skills and time investment. There was only one student programmer, who was inexperienced, available to develop software programs. Additionally, two team members planned to graduate that semester. It was difficult to schedule regular meetings because both students had busy schedules. In conclusion, developing a software program required more experienced members and more time.

Second Iteration of the Prototype

In the following semester, the faculty expert continued to collaborate with professional staff in the DCL and refined the prototype. The majority of students in the development team graduated and left the university. The faculty expert and the DCL professional staff decided to further develop the second iteration of the prototype in Adobe Connect without involving a student team.

NIU has an Adobe Connect server, which is easier for faculty to set up and use in the classrooms without requiring



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 3. Argument Elements by Corresponding Shapes and Arrows. Reprinted from the Journal of Computer Assisted Learning, by P.-S., Hsu, 2015, New Jersey: John Wiley & Sons Ltd. Copyright© 2015 by John Wiley & Sons Ltd. Reprinted with permission.

administrative rights. Adobe Connect allows users to engage in online chat and to communicate verbally in a synchronous way (built-in online chatting and microphone features), which were important features in the prototype. The second iteration of the prototype followed the same design plan in the design document. Figure 5 shows the interface of the prototype. Within the parent-child format, users added new elements using an addition icon in the upper left and right corners on the parent container. Users then choose which element they want to add, which would become a new child under that parent on the screen. The process for adding content to the argumentation element container was to type in the text box. The faculty expert and the DCL professional staff worked on the additional features, such as Auto Save and Progress Checking. The two features required more time and programming skills; therefore, the faculty expert conducted the usability study of the tool without the two features that were undergoing developing.

USERS' EXPERIENCE OF THE PROTOTYPE

As described earlier, the research team identified a need to develop an online graph-oriented collaborative argumentation tool specifically for middle school students. Therefore, the faculty expert decided to conduct usability testing with

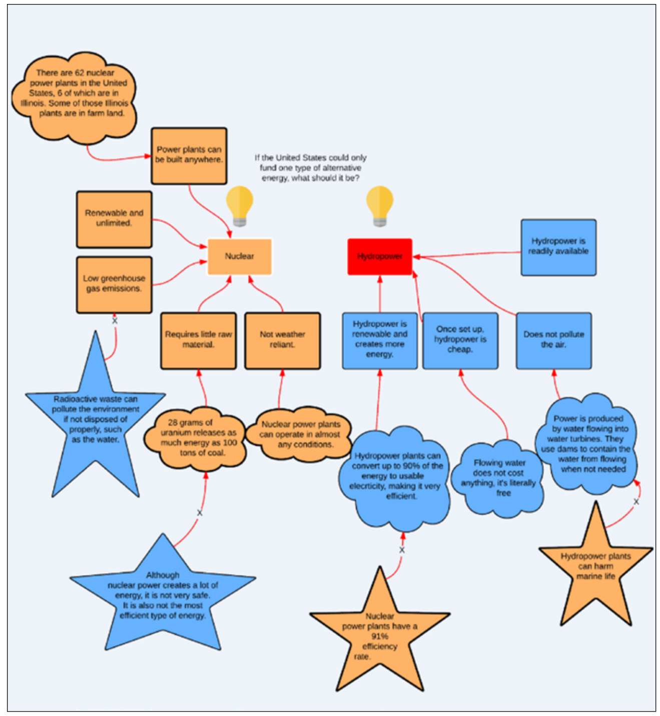


FIGURE 4. Sample Argumentation. Reprinted from the Education Technology Research and Development, by P.-S. Hsu, 2018, Switzerland: Springer International Publishing AG. Copyright© 2018 by Springer International Publishing AG. Reprinted with permission.

FIGURE 5. Interface design in the Second Iteration. Reprinted from Prototype, by P.-S., Hsu, 2017, Illinois: Northern Illinois University. Copyright© 2017 by the Board of Trustees of Northern Illinois University. Reprinted with permission.

middle school students. Nielsen (2012) defines usability as "a quality attribute that assesses how easy user interfaces are to use." Usability testing includes a range of test and evaluation methods, and one of the main purposes of usability testing is to identify issues that keep users from meeting the goals of a software program. The faculty expert used a number of test and evaluation methods to identify the issues in the prototype. There are three phases of usability testing. In the first phase, the usability test was conducted with six students and the faculty expert examined how the prototype could support the representation of argumentation on the individual level. In the second phase, the usability test was conducted with groups of students and the faculty expert examined how the prototype could support the representation of argumentation on the group level. In the third phase, a usability test was conducted with each student to measure how efficiently, effectively, and satisfactorily each student interacts with the prototype. The usability testing in phases one and two focused on how the prototype improves the process of the representation of scientific argumentation by comparing the process to the use of the proprietary tool. The usability testing in phase three focused on how the prototype could be improved.

First Phase

The faculty expert approached a middle school science teacher she had collaborated with in a scientific argumentation on the individual level project earlier in the academic year. All students in the science teacher's classroom had participated in the project and had used a proprietary online graph-oriented tool to support argumentation earlier the academic year (see Figure 4).

The faculty expert began usability testing with six selected students. The purpose was to examine whether the students are able navigate the interface and find the essential features to support the representation of scientific argumentation. The faculty expert set up two computers and identified six middle school students (3 boys and 3 girls) in a quiet room. One computer showed the proprietary tool used earlier (see Figure 2) in the academic year and the other computer showed the prototype. These six students were not necessarily top performers in science but they were good at following instructions and articulating their ideas in class. The science teacher recommended them for participation in the usability testing process. A camera was set up to videotape the computer screen and record each student's vocalizations as well as interviews. The faculty expert spent 40 minutes with each student and used the same procedure. First, the faculty expert asked the students to reflect on the project they had participated in earlier this year. Here are a few sample questions for prompting their reflection:

- How much do you remember about (the proprietary tool)?
- Do you still remember how to use it for the collaborative scientific argumentation activity?
- Please show me how to represent five argumentation skills in different shapes.

The purpose of these questions was to prepare them to compare the proprietary tool and the prototype.

Second, the faculty expert conducted a performance measure for each student. Performance measure is a technique used to obtain quantitative data about test participants' performance when they perform the tasks during usability tests (Soken, Reihnart, Vora, & Metz, 1993). Soken et al. suggested that this method would obtain quantitative data useful for doing comparative testing or testing against predefined benchmarks. To obtain dependable results, at least five user participants are needed. The technique can be used in combination with retrospective testing, post-test interview or questionnaires so both quantitative and qualitative data are obtained. The faculty expert followed the guideline to include six student participants and followed up with an interview with each student participant.

The faculty expert began conducting performance assessment by providing orientation to the prototype and then provided a list of 10 tasks for each student to test with the prototype. The faculty expert observed their performance and tracked whether they performed each task correctly and assigned one point to each task they performed correctly. Students could receive a maximum score of 10 and a minimum score of 0. The tasks included "Click on and drag the position icon and move the textbox" and, "Type in the textbox for the position." The data indicated that all students completed all tasks correctly and received 10 points for their performance measure.

After students completed the performance measure, the faculty expert followed up with an interview. Here are a number of questions:

- Let's look at each tool and please compare the proprietary tool (Figure 2) and the prototype (Figure 5). (Note: The faculty expert brought up the screen of each tool in each computer.)
- Which tool do you prefer? Why?
- Which tool could support you to complete the scientific argumentation activity better? Why?

Overall, all six students preferred the prototype to the proprietary tool in terms of navigation. Adam (pseudonym) compared both tools and commented:

> *"The prototype is easier to use, extremely easy to use such as opening and closing different things. The building icon is guiding through the process. It is not confusing. It is easier in terms of navigation"*

Joy (pseudonym) also compared both tools and commented:

"More user friendly. The prototype is more organized. Box is already there for you. The boxes are more organized. It just automatically connect it to another box."

In the proprietary tool used earlier in the year, the students had to follow the instructions on what shape they would use to represent a certain argumentation component (see Figure 3). They had to drag and drop those shapes from the tool bar. Gary (pseudonym) pointed out the issue with the proprietary tool:

"People might not know what shape to put in. They might not know how to put arrows. The shape will change and the text would go out of the subject."

All six students supported the use of the prototype in scientific argumentation projects. Carl emphasized:

"The prototype is made for this purpose. It is easier to use. It makes you go quicker because you can put your thought right there and you can reply fast. Easier because the icons has been built here. The boxes are made for what you have to do."

In conclusion, compared to the proprietary tool, the prototype allowed students to engage more in the representation of the scientific argumentation process rather than spending time identifying, dragging, and dropping shapes to represent argumentation components.

Second Phase

The faculty expert continued to conduct usability testing with all students (approximately 119 students). There were six classes. In each class, the faculty expert asked students to work with the same team members who participated in the scientific argumentation project earlier in the year. There were between 6 and 7 teams in each class. The faculty expert set up a computer in the front of the classroom and showed the proprietary tool on a projector screen. Each team was provided with one computer that showed the prototype. The faculty expert spent 40 minutes with students in each class and followed the same procedure. First, the faculty expert asked them to reflect on the project they had participated in earlier in the year. Here are a few sample questions for prompting their reflection:

- How much do you remember about (the proprietary tool)?
- Do you still remember how to use it for the collaborative scientific argumentation activity?
- Please show me how to represent five argumentation skills in different shapes.

The purpose of these questions was to prepare students to compare the proprietary tool and the prototype.

Second, the faculty expert conducted performance measures for each team. The faculty expert followed the guideline provided by Soken et al. (1993) to study a total of 37 student teams in six classes and followed up with a focus group with all student teams in each class. The faculty expert conducted performance measures with the student teams because she intended to explore what challenges the student teams would have when they used the prototype for the actual scientific argumentation activity. Thus, in the performance measure, the faculty expert paired two teams who tested the prototype. Two video camcorders were set up to videotape the students' vocalizations, as well as conversations in the focus groups.

The faculty expert began conducting performance assessments by providing an orientation of the prototype and a list of ten tasks for each student team to test with the prototype. The faculty expert instructed each student team to observe its own performance and asked one student to check the tasks on a performance measure sheet when the team was able to perform the task correctly. The faculty expert assigned one point to each task the teams performed correctly. Each team could score a maximum of 10 point or a minimum of 0. The tasks included "Click on and drag the position icon and move the textbox" and, "Type in the textbox for the position." The data indicated that 36 student teams, except one, completed all tasks correctly and received 10 points for their performance measure. The other student team was not aware they had to check the box to receive a point. Due to time constraints, the student teams were not involved in the authentic collaborative argumentation task during usability testing as we reflected on the design.

The performance measure sheet also included space for each student team to write comments. Overall, their comments were positive, such as "It was pretty basic and easy to use;" "Easy, can keep things organized;" "It is easy and efficient;" and "Simple." However, they also provided constructive comments to improve the prototype in terms of interface design and functionality. The feedback included "Make icon and text size a bit bigger;" "When typing, the words are blocked by the text box's scroll bar;" "There is no spell check;" and "Add the delete function."

After students completed the performance measure, the faculty expert conducted a focus group in each class. Here are a number of the questions asked:

- Let's look at each tool and please compare the proprietary tool and the prototype. (Note: The faculty expert brought up the screen of each tool in each computer.)
- Which tool do you prefer? Why?
- Which tool could support you complete the scientific argumentation activity better? Why?

Overall, students in the six classes preferred the prototype rather than the proprietary tool in terms of navigation. The students in Class A compared both tools and commented:

> *"We like the prototype because it is more structured than [the proprietary tool]. It is easier to navigate."*

The students in Class E also compared both tools and further commented:

> *"We like this one, it is easier to navigate and it is more specifically designed for argumentation, so it is easier for us."*

However, students also pointed out areas that could be improved in the prototype. One class pointed out an issue with the prototype tool:

> *"Do you see the boxes, the scroll thing on the side? Some of the words get cut off by that and you cannot always see the words."*

A number of classes emphasized the importance of deleting the boxes:

> *"Be able to delete the boxes that I created. Make the size of boxes bigger."*

In conclusion, the data from the comments on the performance measure sheets and the focus groups indicated that compared to the proprietary tool, the prototype allowed the students to engage more in the representation of scientific argumentation process.

Third Phases

Additionally, the faculty expert conducted usability testing with each individual student by asking each student to fill out the System Usability Scale (SUS) after trying out the prototype. The SUS provides a reliable tool for measuring usability. It consists of a 10-item questionnaire with five response options for respondents from Strongly agree (5) to Strongly disagree (1). It was originally created by John Brooke in 1986 and has been used to evaluate a wide variety of products and services, including hardware, software, and applications. It was found that the SUS was highly reliable (alpha = 0.91) and useful over a wide range of interface types. In the SUS, items 1, 3, 5, 7, 9 are worded in a positive way, while items 2, 4, 6, 8, 10 are worded in a negative way. Here is a list of the ten statements:

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly
8. I found the system very cumbersome to use
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

A graduate student assisted the faculty expert in the data analysis process of the SUS. Each student's score for each question was converted to a number ranging from 1 to 5, added together, and then multiplied by 2.5 to convert the original score of 0-50 to 0-100. As suggested by Bangor, Kortum, and Miller (2008), a score of 68 or above indicates an acceptable interface. Among the 119 students, 90 students provided a score of 68 or above, and 75% of the students evaluated the prototype as having acceptable usability.

We further analyzed the score of each item for the students who provided a score below 68. We identified that this group of students responded "5" (Strongly agree) or "4" to items 4 and 10, but they responded "1" (Strongly disagree) or "2" to items 7 and 9. These four items evaluate learnability, which indicates how easy or difficult it is to learn to use a system or interface effectively. The faculty expert shared the results with the students and conduced a follow-up discussion with them. The students suggested developing a tutorial in both paper and online forms to address the learnability issue.

SUMMARY

The objective of this project was to develop an online graph-oriented collaborative argumentation tool for middle school students. Overall, the results of the usability testing suggested that the prototype is targeted at the representation of scientific argumentation and the features in the prototype are helpful for students to achieve their goal. The research team led by the faculty expert has fine-tuned and added features suggested by the students. The research team continues to develop the tutorial in both the paper and online forms. The faculty expert plans to conduct a second round of usability testing after the features suggested by the students and the tutorial are fully developed.

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