The Aggregation Tool: Toward Collaborative Inquiry in Design-Based Science and Engineering Projects

Ethan Danahy, Ph.D.[1] [Morgan Hynes, Ph.D.,[2] Leslie Schneider, Ph.D., Danielle Dowling]

Abstract – A growing body of research has shown two things: (1) collaborative design-based inquiry activities show remarkable gains in students' understanding of science and (2) such activities are largely absent in the classroom because they can be challenging to implement. In order to rectify the current situation, the Interactive Learning and Collaboration Environment, or InterLACE, project seeks to design a suite of technological tools that facilitates class-wide collaborative sense-making. To that end, we have created an idea aggregation tool that enables students to upload their verbal and pictorial representations of science concepts to a Web-based platform that can then display these artifacts on a centrally located screen, thus encouraging discussion and debate among the students in an iterative process, which will not only help refine their thinking but also grant them ownership of the learning process.

Keywords: collaboration, sense-making, design-based, inquiry, science

INTRODUCTION

Over the past decade, the National Science Education Standards have shifted emphasis from knowledge acquisition and presentation of information to instructional methods that encourage active student learning through collaborative hands-on design-based inquiry activities centered on real-world problems [22, 24]; and a growing body of research confirms that students learn science more deeply if they engage in such activities [5, 9, 15, 28]. Other research has demonstrated that design-based inquiry helps students gain process skills such as theory building, argumentation, and collaboration [10, 16, 23] and improves their attitude toward science [13].

As our understanding of learning has evolved so has our realization of the important role that technology can play in supporting design-based inquiry science when combined with appropriate pedagogies [1, 12]. In particular, technologies such as simulations of authentic investigations [33, 34], data analysis tools [34], and access to social networks of learners and experts [33] are well suited to support design-based inquiry science. Additionally, myriad software tools have been developed to facilitate collaborative learning, and they have reaped promising results such as enhanced performance outcomes, more positive attitudes toward learning, and a higher quality of social interaction [30].

Moreover, technology provides opportunities for real data collection and experimentation in virtual environments [7, 19]. Technology can also facilitate immediate feedback, which benefits both teachers and students [25], and it can support cognitive processing and shared cognitive load [21].

The notion that design-based inquiry challenges can foster science learning is further buttressed by the theoretical perspectives of situated cognition and distributed cognition. From a situated cognition viewpoint [3, 17], we can describe design as a sociocultural activity, which situates the use of science concepts and thus lends everyday meaning to them. The situated cognition standpoint, which is consistent with Vygotsky's theory of the sociocultural nature of learning, asserts that an individual's cognition is embedded in and inseparable from the individual's

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[1] Tufts University Center for Engineering Education and Outreach, 474 Boston Avenue, Curtis Hall, Medford, MA 02155, ethan.danahy@tufts.edu

[2] Tufts University Center for Engineering Education and Outreach, 474 Boston Avenue, Curtis Hall, Medford, MA 02155, morgan.hynes@tufts.edu

situation and activity in a community of practice [3]. In other words, *concepts* are always enmeshed with *culture* and *activity*, and the meaningfulness of learning is constrained by all three conditions. We posit that design-based inquiry learning is one kind of activity that requires the use of both science practices and science content knowledge.

The theoretical basis provided by situated cognition theory is strengthened by the theory of distributed cognition [14, 29]. During a design activity, an individual's knowledge about related science concepts can be unloaded not only to the tangible products that are created as a consequence of the activity but also to the other participants in this process. This sharing of knowledge may be one example of distributed cognition, which Bell and Winn [2] define as a person's individual cognitive acts plus the augmentation of other people, external devices, and cultural tools. The notion of distributed cognition implies that cognition includes both the social and physical environments. From a distributed cognition point-of-view, we can propose that engineering design may spread the cognitive load of achieving scientific understanding among the classmates and the teacher, thereby increasing the individual student's capacity for science learning.

An important element of the design-based inquiry process is collaborative learning. According to Roschelle and Teasley [26], "collaboration is a process by which individuals negotiate and share meanings relevant to the problem-solving task at hand.… Collaboration is a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem" (page 70). Collaboration also involves cooperation, but it mainly focuses on doing work together.

Although these approaches are supported by research and lauded by educators as benefiting students, they are still not widely used in the science classroom [4, 8]. Design-based inquiry lessons and meaningful group work can be challenging to implement; they require changes in curriculum, instruction, and assessment practices that are often new for teachers and students [18, 20]. According to Dillenbourg and Jermann [6], technology can empower teachers to dynamically orchestrate all attendant classroom activities. The role of researchers is not one of agents of "technology transfer" but as "innovation guides, who help schools…better understand how needs, approaches, benefits, and alternatives fit together compellingly and cohesively" [27] in order to develop solutions that address the obstacles to the successful execution of design-based inquiry lessons.

The InterLACE Project

Toward the goal of supporting the implementation of design-based inquiry projects in high school physics education, the Interactive Learning and Collaboration Environment, or InterLACE, project is in the process of creating a suite of software tools to support design-based inquiry and collaboration in the classroom. The software tools will aim to promote both sharing of ideas and information and collaboration among students and student groups. Previous software-development work around a product called RoboBooks by members of the InterLACE team highlighted the need for additional technological support to promote collaboration and sharing. The RoboBooks tool, an interactive digital workbook, appeared to reliably deliver content to and collect responses from students, but as outlined in Peter Sneeringer's 2010 thesis, *The Sharing of Academic Content Through the Use of the RoboBooks Website*, it did not do well in promoting sharing and collaboration [31]. Sneeringer investigated the implementation of the RoboBooks software and its associated Web-based environment as a platform for sharing and collaboration. Focusing on college classrooms, the study characterized student sharing behaviors (looking at personal vs. academic material) and analyzed the current RoboBooks software and test website as platforms for sharing and collaboration. Sneeringer found that students needed external factors—for example, explicit requirements embedded within the activity—to encourage sharing behavior when it came to academic material. His research pointed to the three main technical requirements for facilitating the sharing of content: streamlined tools for uploading and retrieving remote content, descriptive images and summaries that expedite browsing, and expressive communication tools enabling real-time conversations among members. Our approach builds on these preliminary findings and integrates research and pedagogy in the areas of inquiry-based science, instructional scaffolding, and computer-supported collaborative learning (CSCL).

Accordingly, the InterLACE software will provide a more holistic approach in support of collaborative reasoning and problem solving than the more tool-based approach employed within the RoboBooks prototype. Ascribing to the findings of CSCL researchers, "the goal for design…is to create artifacts, activities, and environments that enhance the practices of group meaning making" [32]. We view technology development as an iterative and transformative process that involves teachers and students in a collaborative participatory design process. Therefore, we have a assembled a five-member teacher design team, which collectively represents a diverse pool of candidates not only in terms of years of teaching experience but also in terms of the socioeconomic and ethnic student populations they represent. The greatest value of having a design team comprised of teachers is that as they co-design a tool for their classrooms, they experience the collaborative inquiry process firsthand.

There are several commonalities in how classroom instructional practice is structured in most inquiry approaches to science learning. Mostly, students work in a group in which collaboration and communication are vital. As they attempt to solve science problems, students are always expected to engage in written or pictorial record keeping. In addition to their individual accounts and reflections, students think about their designs as they engage in class-wide discussions. Students can also iteratively apply what they are learning by getting real feedback on and ongoing assessment of what they've done so far, receiving the guidance they need to explain what happened in the course of their experiment if it was not what they expected, and having an opportunity to revise and refine their design ideas and justifications. More important, throughout design-based science, teachers provide scaffolding to help students connect different phases of the process and to guide them on how they should incorporate science ideas and careful reasoning into their design solutions. Researchers believe that this scaffolding is essential for preventing students from merely tinkering. We will incorporate all of these principles into the design of the InterLACE software and associated physics learning modules.

DISCUSSION: THE AGGREGATION TOOL AND A POSSIBLE IMPLEMENTATION

With the aforementioned principles in mind, as well as the information we gathered through interviews with and classroom observations of our design team teachers, we have created our first tool, the aggregation tool, for InterLACE's software platform. The aggregation tool will collect ideas that students can express verbally or pictorially and then easily push to the aggregation tool via keyboard or camera. The teacher can view the students' ideas through an administrator's dashboard and display them on a centrally located screen. This tool will enable individual students to contribute to a class-wide discussion that can start with a presentation or a simple question and continue into hypotheses generation, lab activity selection, data-set sharing, and finally collaborative sense-making. The progression of such an activity (see Figure 1) would include many "reflection points" at each step in the process during which group work (represented by subscripts 1 through N in Figure 1) is automatically collected and stored via the aggregation tool, making it easy for teachers to facilitate class-wide discussions and allowing students to share their work with their classmates and refer back it when the need arises. This functionality will encourage students to reflect on and interpret what they are doing and how the underlying science connects to their project goals. Then, before moving on, each group will view and comment on others' work and thinking, in order to glean new ideas or offer advice to their classmates. By cycling through myriad individual and group processes, students can engage in the inquiry process as they consult with members of their group or other groups about the experiments or design challenges they have devised around the same science or engineering concept. We believe, in this way, the aggregation tool provides a unique opportunity for teachers and students to actively collaborate across groups, which is often difficult to accomplish in a classroom setting.

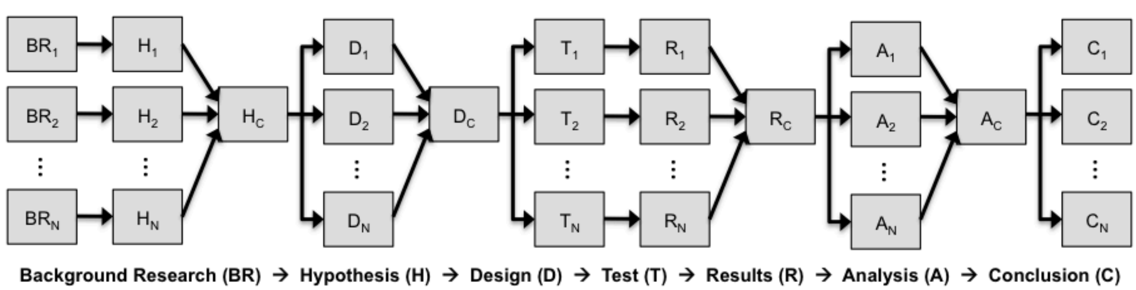

Figure 1: Flow chart showing the reflection and collaboration process via the aggregation tool, in which group work (subscripts 1 through N) is combined into a class summary (subscript C) available for group review and discussion.

Described here in more detail is an example of the students' experience as they proceed through an activity using the aggregation tool. Small groups of students would be asked to investigate a physics question, design and carry out an experiment, and collaborate on their work with their classmates:

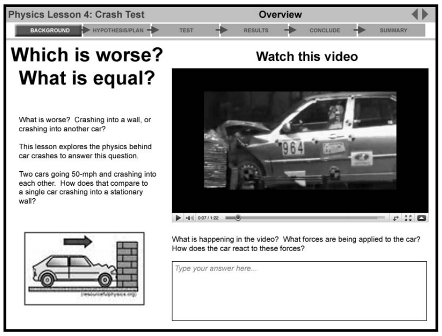

Figure 2: In the physics challenge shown above, students are asked to ponder the forces experienced by cars during a collision.

The students would be presented with a physics challenge (for an example, see Figure 2). The teacher might offer a presentation that features movies, slides, and pictures to engage students in the content. The presentation would then be followed by a question that prompts students to share their thinking about the concept at hand (e.g., Would it be better to be going 50 mph and hit another car traveling at the same speed or crash into a stationary wall?); they would push their ideas to the aggregation tool, after which the teacher would share them with the rest of the class to encourage subsequent discussion, then certain hypotheses would be democratically selected for testing.

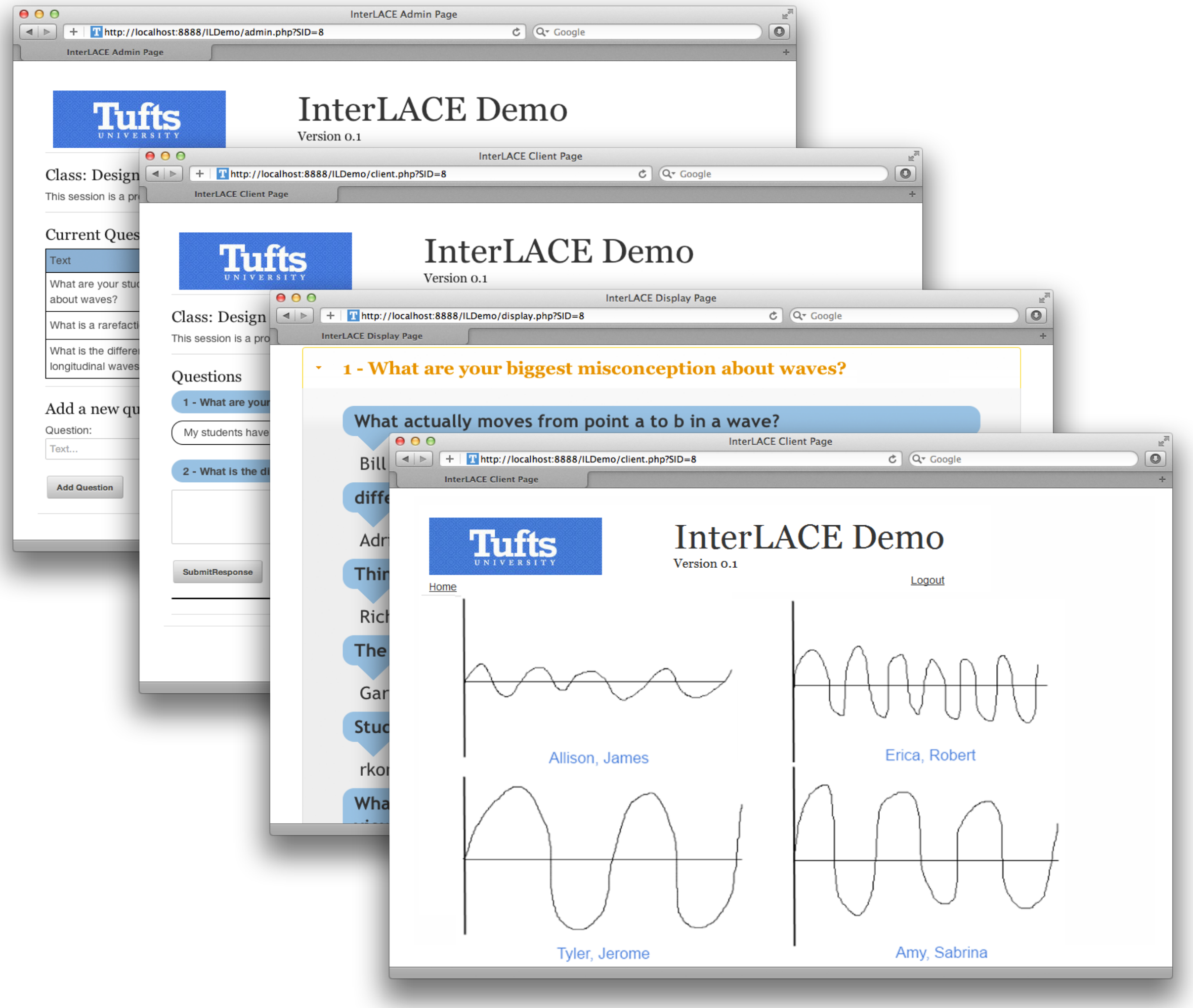

Figure 3: Screen shots of the aggregation tool.

Based on the respective hypothesis they support (e.g., the force experienced would be the same in each scenario), students would assemble into groups and create a lab activity. The groups would upload their proposed lab activities to the aggregation tool, and a second round of discussion would ensue, during which the groups would justify their reasons for choosing their respective lab activity and consider and critique other groups' proposed experiments.

Once the lab activities are refined through student and teacher input, each group would execute its experiment, record the data, and then share it with the teacher and the rest of the class via the aggregation tool. The teacher would not only be able to share the various data sets but also have the capability to show how they converge or diverge and what outliers and trends exist among them. After a third round of discussion concerning the data sets and other notable results, the students would analyze their own data in light of the class-wide data, and a final round of discussion would hopefully promote a collaborative consensus. A summary screen would provide a last look at all the documentation generated throughout the process. Each student could use this resource for lab write-ups, including summaries of the reasoning behind his or her group's findings and what he or she learned about design, use of evidence, and so on.

CONCLUSION

Science educators are facing increased challenges with mounting accountability for raising science achievement among their students. As the demands for more effective teaching and a more coherent focus on science skills grow, an expanding body of research points to four major teaching practices that improve a student's grasp of science content and process skills: namely a design-based inquiry approach to teaching, explicit scaffolding of instruction, the use of technology, and collaborative learning. Despite the overwhelming evidence, these methods have failed to gain traction in science classrooms because teachers perceive them as difficult to implement [11].

The InterLACE software will offer students and teachers more flexible and efficient tools that address some of these implementation challenges. For example, a significant obstacle to using an inquiry approach in the classroom is the lack of experience teachers possess in engaging their students in argumentation and convergent sense-making. InterLACE will address this issue by developing tools that grant students a forum for their ideas and give teachers a way to aggregate and analyze this data. We realize that a software tool alone is not the ultimate cure, therefore we are equally focused on providing professional development that would instruct teachers on how to facilitate a collaborative inquiry process during design-based projects. Going forward, we plan to test a number of instructional approaches using the aggregation tool, develop complementary tools, and authentically engage teachers in the inquiry process by asking them to partner with us on the design of InterLACE's software.

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Ethan Danahy, Ph.D.

Ethan Danahy is a research assistant professor in the department of computer science at Tufts University. Danahy received a B.S. and an M.S. in computer science in 2000 and 2002, respectively, and a Ph.D. in electrical engineering in 2007, all from Tufts. In addition to teaching, he acts as the engineering research program director at Tufts University's Center for Engineering Education and Outreach (CEEO), where he manages educational technology development projects while researching innovative and interactive techniques for assisting teachers with performing engineering education and communicating robotics concepts to students spanning the K–16 range.

Morgan Hynes, Ph.D.

Morgan Hynes is a research assistant professor at the Tufts University education department and the education research program director for the CEEO. Hynes received both his B.S. in mechanical engineering in 2001 and his Ph.D. in engineering education in 2009 at Tufts University. In his current positions, Hynes serves as PI and co-PI on many funded research projects focused on engineering education in K–16 settings. He is particularly interested in how students and teachers engage in and reflect upon the engineering design process. His research includes investigating how teachers conceptualize and then teach engineering through in-depth case study analysis. Hynes also spends time working at Boston's Sarah Greenwood K–8 school assisting teachers in implementing engineering curriculum.