

## Reflectively Prototyping a Tool for Exchanging Ideas

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**Abstract:** We describe our approach to prototyping an iteration of the Idea Manager, a tool integrated into an online science inquiry environment. Students use the Idea Manager to track ideas as they encounter new information, and reflect upon, sort, and distinguish ideas toward integrating their understanding. To explore the value of collaborative features, we designed a hybrid online/offline activity to facilitate students exchanging ideas with the Idea Manager. Based on student interviews and case studies, we identify aspects of collaboration to inform design features for enabling the meaningful exchange of ideas. Whereas most design accounts focus on the evaluative role of prototyping, this study highlights its reflective use, and its role in involving multiple stakeholders in rapid iterative cycles of establishing requirements, building alternatives, and testing. By documenting these iterative design activities, this study informs both the theory and practice of designing collaborative educational technologies.

### Reflective Prototyping and the Knowledge Integration Framework

Prototyping can inform both the theory and practice of designing collaborative learning technologies: It encourages reflection and enables early feedback from users (Saffer, 2010; Schon, 1990), serves to externalize and support the development of ideas, and helps filter aspects of interest for investigation (Lim, et al., 2008). But educational technology design tends to be practically rather than theoretically driven (Bennett & Oliver, 2011), and researchers rarely document these mid-stages of their design processes, or else they focus on the evaluative rather than on the reflective functions of prototypes (Lim, et al., 2008).

We describe how prototyping allowed us to filter and study aspects of students' collaborative learning to inform design iterations of a theoretically-driven technology: the Idea Manager. The Idea Manager is a tool integrated into the Web-based Inquiry Science Environment (WISE, wise.berkeley.edu) and designed to support students building evidence-based explanations during online science inquiry units (see Figure 1).

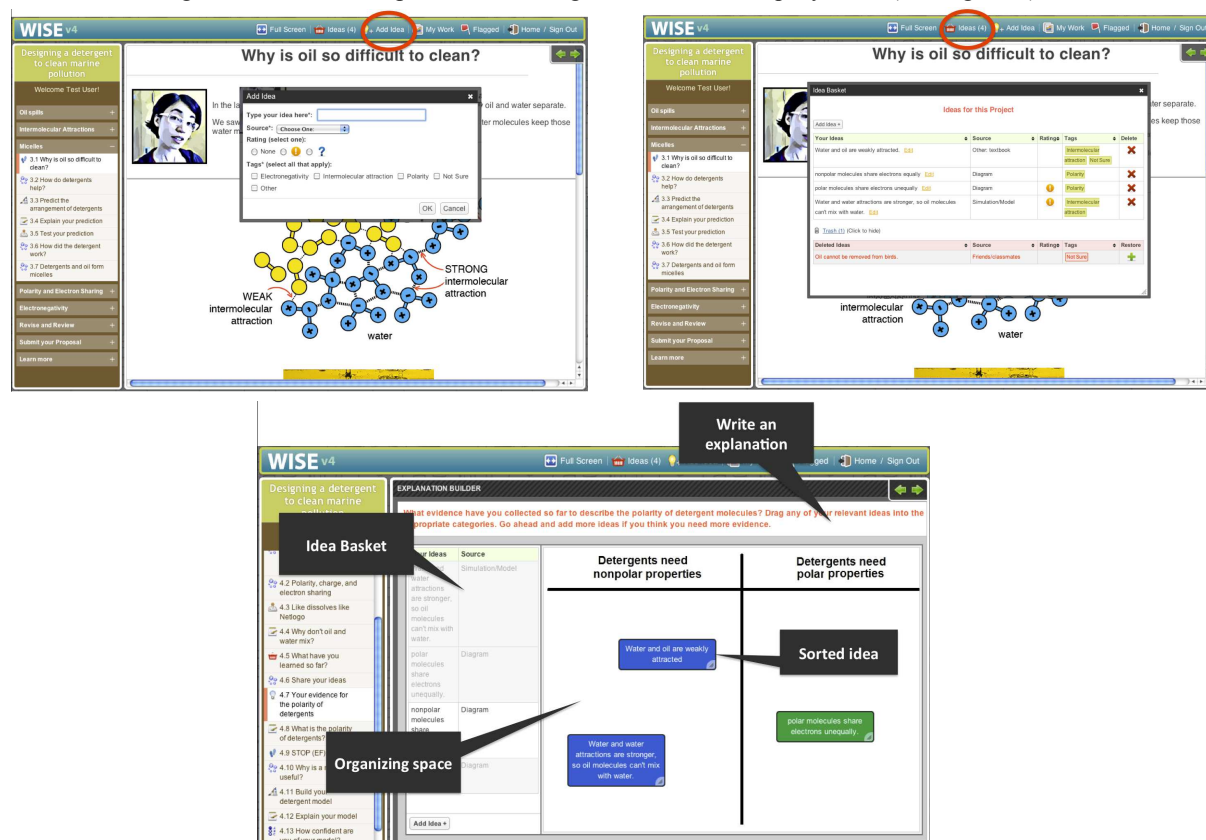


Figure 1. The Idea Manager's two components: (1) A persistently accessible repository for ideas, into which students type and revise entries (<150 characters) and apply author-supplied tags and labels (top left and right);

- and (2) A dynamically linked Explanation Builder space, into which students drag and sort ideas into author-specified categories before writing an explanation (bottom).

Building on previous educational technologies (e.g., Bell, 1997, Zhang & Quintana, 2012), the Idea Manager helps students manage complexity and support production (Blumenthal, 1991). It breaks down the process of explanation into the discrete steps of gathering, sorting, and distinguishing information encountered; and guides understanding by making the process of reflection explicit, deliberative, and continual (Beeth, 1998). The Idea Manager's design is guided by Knowledge Integration (KI, Linn & Eylon, 2011), a constructivist pedagogy that takes a knowledge-as-elements perspective on learning to incite conceptual change (Özdemir & Clark, 2007). Recognizing that their existing understanding may be fragmentary and idiosyncratic (diSessa, 1993), KI instruction elicits students' prior knowledge and encourages them to confront and distinguish among their often conflicting ideas. Classroom implementations demonstrate the usefulness of the Idea Manager for eliciting and making visible students' ideas (Matuk & King Chen, 2011). Logs of students' interactions with the Idea Manager moreover lend insights into how students integrate ideas over the course of a unit, and inform targeted curriculum revisions (McElhaney, et al., 2012).

### Methodological Approaches to Exploring Requirements for a Collaborative Tool

Our design process integrates user-centered design and Agile Methods of software development (da Silva, et al., 2011), and emphasizes rapid iteration between establishing requirements, designing alternatives, and building and evaluating prototypes. Through the early and regular involvement of users, this approach permits simultaneous exploration of how users and the establishment of technical and pedagogical requirements. Thus, we first elicited ideas from WISE users worldwide, including 20+ middle and high school teachers, and 30+ WISE researchers and WISE developers. Interviews, discussions, workshops, and a survey revealed interest in extending the Idea Manager to support student collaboration. Respondents saw potential in the tool for students to practice communication; for studying the impacts of peer exchange on perceptions of science inquiry; and for operationalizing and researching knowledge exchange. This investigation also revealed open questions over how to orchestrate the sharing of ideas. Should students see the ideas of all their peers, or of selected peers? Should contributing and/or citing others' ideas be anonymous or rewarded? Should teachers facilitate the exchange of ideas, and if so, how? One way to investigate these questions is to implement and observe students' use of collaborative features. But this technology-first approach risks masking the incidental face-to-face collaborative interactions that can be valuable for learning. Instead, we chose a learner-first approach, and designed an offline activity in order to identify incidental aspects of face-to-face collaboration, which would then inform specific design features in a collaborative learning tool.

### Methods: The *Detergents* Unit and Collaborative Idea Manager Prototype

We integrated the Idea Manager into *Designing a detergent to clean marine pollution*, a freely available unit authored in the Web-based Inquiry Science Environment (WISE, (<http://wise.berkeley.edu/webapp/vle/preview.html?projectId=4369>)). In the unit, students explore the chemistry of detergents and use the Idea Manager to gather and distinguish ideas on electron sharing, electronegativity, and polarity, before writing explanations for how detergents cleans birds endangered by marine oil spills. To explore the potential for a collaborative Idea Manager, we designed an *Idea Exchange* activity, which prompted students to share the contents of their Idea Baskets with another student team; identify ideas that were the same and different between their Baskets; suggest ideas to the other team; and label newly added ideas as Important or Not Important.

Participants were 170 students of five teachers at a high school in the United States. Student pairs worked on the *Detergents* unit for 5-6 consecutive school days while their teacher and a researcher circulated to offer assistance as needed. Data include classroom field notes, videotapes of nine pairs of student dyads during the *Idea Exchange* activity, and end-of-unit interviews with 15 students (2-3 students per 15-20-minute session), in which we asked for students' impressions of the unit, of the utility of the Idea Manager, and their experiences during the *Idea Exchange* activity. Our video analyses identified incidents during the *Idea Exchange*, in which collaboration appeared to promote KI (e.g., when students contributed new ideas and engaged in distinguishing among them). Our interview analysis characterized students' perceptions of the value of the *Idea Exchange* activity, and of a mediating technology. Below, we illustrate three aspects of collaboration that emerged from our prototyping, and how these informed iterations of the Idea Manager.

## Major Findings

### Exposure to diverse ideas through increased peer interaction

Students interviewed expressed interest in seeing their peers' ideas. As one student described, the *Idea Exchange* activity showed how the other students "saw it different than us. They would tell us 'Oh, but this...

and then we would tell them.” Another student noted that “it was useful to see like how other people, like what their views of the project were, and how, what kind of notes they were taking.” The *Idea Exchange* not only exposed students to different ideas, but also broadened their social encounters. One student noted “I don’t talk a lot in this class,” but in the *Idea Exchange*, she and her partner collaborated with peers outside their social circles. Thus, students appeared to value the opportunity to discuss divergent perspectives with their peers. Indeed, research on brainstorming and group creativity suggests that early exposure to others’ ideas has positive impacts on the speed with which individuals generate new ideas, as well as on the quantity, diversity, and semantic organization of ideas generated (Nijstad, Stroebe, & Lodewijkx, 2002).

At the same time, our data revealed a number of logistic issues with coordinating the sharing of ideas. Because their work was self-paced, it was rare for a sufficient number of teams to have simultaneously arrived at the *Idea Exchange* activity, which resulted in students waiting idly for others to catch up, or else moving ahead and forgetting to later return to the activity. Some students indicated in their responses to the embedded prompts that their partner teams’ ideas were too few or too similar to spur discussion. In one student’s description of this “awkward” situation, a partner might ask, “What was your ideas?” And a lot of the ideas people would write... it would be something that I probably already knew or thought of.” This challenge limits the diversity of ideas students encounter, and forfeits chances to learn from one another (cf. Hsi & Hoadley, 1997). To increase students encountering diverse ideas, a text-analysis function might help automatically partner teams based on similarities or differences of their ideas. This same feature might help coordinate asynchronous participation, and eliminate the time students spent idly waiting for others to catch up.

### Orchestrating Meaningful Sharing of Ideas

Face-to-face, students not only present their ideas, but benefit by questioning, explaining, and elaborating upon them (Howe & Mercer, 2012). For example, when one student pair questioned another’s use of the term *electron sharing*, the teams proceeded to negotiate a shared conceptual understanding (see Figure 4, left). Students are themselves conscious of the value of face-to-face sharing. On being asked whether she would prefer to exchange ideas face-to-face or online, one student replied “it’s always better like, face-to-face, because that’s when you actually discuss the main topic, and it’s just not reading it, and (...) just putting it in your Basket to get more ideas.” Yet, we observed face-to-face interactions in which discussions failed to develop beyond dictating entries for others to transcribe (see Figure 4, right). A digital platform would easily avoid the need for dictating entries, but it must also encourage careful consideration of one another’s ideas. Threaded, scaffolded discussion around individual entries, for example, might encourage and capture more elaborated discussion (cf. Hoadley & Linn, 2000; O’Neill & Gomez, 1994).

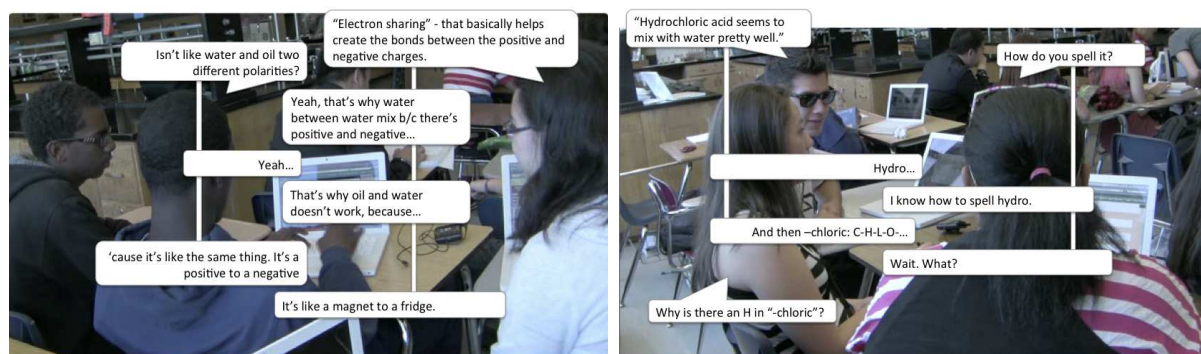


Figure 4. The *Idea Exchange* activity engaging students in distinguishing ideas (left), and devolving into a dictation exercise (right).

### Vulnerability, Validation, and Social Exclusion

Sharing unrefined ideas puts one in a state of vulnerability, and how the recipient responds can have either alleviating or worsening effects. In one case, Vitaly apologizes to Harshan because he and his partner have collected only one idea, and, he adds, “I don’t know if it’s right.” Harshan replies, “That’s a good idea,” and reminds Vitaly “It’s an idea. It’s not right or wrong, it’s just an idea.” Pointing out “We both agree that the atoms don’t have a strong attraction so they won’t bond together,” Harshan then leads a conversation to further elicit and distinguish each of their ideas. In a contrasting case, Elliott shows visible dislike for Armando, and tells his partner Derek, “I’m not talking to him.” Instead of engaging Armando, Elliott and Derek work alone to answer the unit prompts as Armando silently faces away from them. Once finished, Armando abruptly picks up his laptop and returns to his desk. These episodes demonstrate a range of social dynamics and their implications for learning. Whereas Harshan’s validation of Vitaly’s ideas shows how collaboration can encourage meaningful sharing of ideas, Elliott, Derek, and Armando’s failure to achieve intersubjectivity results in a missed

learning opportunity (cf. Barron, 2003). Technology might anticipate these outcomes by allowing anonymous participation, thereby foregrounding ideas and promoting contributions (cf. Hsi & Hoadley, 1997).

## Conclusions and Implications

Our prototype highlights the value of peer interaction for exposure to diverse ideas; the impacts of favorable and adverse social dynamics; and logistical considerations for orchestrating the meaningful exchange of information. Without attempting to identify broad generalizable patterns, these cases illustrate the spectrum of collaborative interactions afforded by face-to-face and technology mediated collaboration, and define a baseline for further study. By documenting the co-evolving design and development of a theory-driven tool, this paper informs both the theory and practice of designing collaborative learning technologies.

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