Title: Investigating, Visualizing, and Discussing Chemistry with ChemSense

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Abstract

ChemSense is an NSF-funded research and development project designed to examine the impact of representations, chemical investigations, and discourse on chemistry learning. The ChemSense computer-based learning environment allows students and instructors to collaborate in the investigation of chemical phenomena, collect data, build representations of these phenomena, and participate in scaffolded discourse to explain these phenomena in terms of underlying chemical mechanisms. Research indicates that ChemSense is effective in supporting student representational use and chemical understanding, and suggests a need to augment and examine the role the teacher can play in supporting and assessing students' use of ChemSense.

Introduction

ChemSense is a research and development project funded by the National Science Foundation (REC-9814653) to examine the impact of representations, chemical investigations, and discourse on chemistry learning (Schank et al., 2000). Our work intersects several theoretical approaches to learning, which include collaborative project-based investigations (Krajcik et al., 1998), representational competence (Kozma & Russell, 1997), the design of chemistry curriculum (Coppola, personal communication), and knowledge building (Scardamalia & Bereiter, 1996). ChemSense includes a set of tools (software and probeware) and curriculum activities that draw on this theory to scaffold students' learning of chemistry. Research on the use of ChemSense indicates it is effective in supporting student representational use and chemical understanding. Our analyses also indicate the need to extend the tools and our research to augment and examine the role the teacher can play in supporting students' use of ChemSense.

The ChemSense Knowledge Building Environment (KBE) is virtual workspace for students to express and discuss ideas in chemistry. More specifically, the KBE supports the sharing, viewing, and editing of a variety of representations, including text, images, graphs, molecule drawings, and animations. Users can annotate existing items, create new items that build on other students' work, classify items by semantic type (as in CSILE; Scardamalia & Bereiter, 1996), and export their work in Web format for application in other venues. The software is written in Java and features a cross-platform client-server architecture. Laboratory investigations are supported through the use of PASCO probeware and software for real-time data collection and data display.

Our current curriculum activities are designed around a set of five key time-dependent dimensions associated with the particulate nature of matter and chemical reactions: change in (a) connectivity, (b) molecular geometry, (c) aggregation, (d) state, and (e) concentration. Taken together, these dimensions portray the molecular world imagined by chemists to account for observable phenomena. All involve changes in molecular and supramolecular structure that correspond to critical aspects of chemical reactivity. These dimensions cut across traditional chemical topics, such as acid-base reaction, electrochemistry, solubility, and thermodynamics. The curricula follow an investigation-based approach in which students ask questions, design investigations and plan procedures, construct apparatus and carry out investigations, analyze data and draw conclusions, and present findings. Currrently, we have two complete, multi-week modules, “Solubility” and “Soap”, and are currently in the process of working with teachers to develop additional modules

Research Activities

ChemSense has been designed and improved through a series of baseline and design studies (Schank et. al, 2000), and most recently through classroom use at San Leandro High School (California) and at the University of Michigan. A variety of qualitative and quantitative methods were used to evaluate its impact, including student interviews, video analysis, and scoring of pretests, posttests, retention tests, and representations created by students. Here, we briefly discuss the findings from our San Leandro study in December 2000.

Working with high school students using our Solubility module, we found that students who created more drawings and animations in ChemSense over a 3-week period showed greater representational competence (ability to create and analyze representations) and deeper understanding of geometry-related aspects of chemical phenomena in their animations. Specifically, we found a significant, positive correlation between the number of drawings and animations created in ChemSense and the quality of the animations produced, as scored by multiple raters using our chemical geometry and representational competence rubrics ($p<.05$). Students using ChemSense also showed significant improvement in representational competence and in their understanding of connectivity and geometry from pre- to posttest ($p<.05$). These findings suggest that the use of ChemSense as a representation “creation” tool facilitates representational ability and chemical understanding of underlying, nanoscopic mechanisms. Video analysis also showed that use of the tools requires students to think carefully through specific aspects of chemical phenomena, such as the number of molecules involved in a reaction, the particular bonds created in the reaction, the bond angles, or the sequence of steps in a reaction. Throughout the collaborative sessions we videotaped, students used the representations to both develop and reveal their understandings of chemical phenomena.

We also found that students who started out with the most limited representational competence demonstrated the greatest improvement in representational competence over time. Specifically, we found a significant, negative correlation between pretest scores and gain (posttest minus pretest) scores ($p<.05$). This suggests that ChemSense may be an effective way to level the playing field between students by providing them, regardless of their initial representational competence or attunements, with an effective way to generate and communicate chemical ideas.

Our high school teachers had positive impressions of the tool and were “amazed how focused the students were” (Larson, personal communication), but they were unclear on how to assess or support their students' work. The teachers noted that it was difficult for students to transfer their prior understanding of, and approach to, chemistry into the computer-mediated environment, and were challenged by the process of constructing their own understanding. The teachers would have wanted to both model and guide the students in this process, but had limited experience with ChemSense tools, a peripheral relationship to the implementation of study itself, and, therefore, were in a difficult position to help students pursue productive leads in their thinking.

Implications and Future Research

Our findings indicate ChemSense’s affordances as a representation creation and manipulation environment and highlight its potential to foster students’ ability to use representations in expressing and understanding chemical ideas. We have identified three main areas for improvement and further investigation. First, our high school studies thus far have focused primarily on one of the five chemical dimensions—geometry—as well as representational competence. To investigate how ChemSense supports students’ understanding of the additional chemical dimensions, we need to extend the current set of curricular activities. Second, our studies thus far have been limited to 4 weeks or less.

Longer-term studies are needed to fully understand the impact of ChemSense and how students' chemical understanding and representational competence change over time. Third, student learning can be enhanced by the greater use of formative assessment within ChemSense, as well as greater support for teachers in their use of the ChemSense tools and development of ChemSense-based curriculum.

Based on our findings and our hypothesis that representational tools and activities can afford deep levels of student learning, we are currently investigating the following research questions in our second round of NSF funding:

- During the course of one academic term in a ChemSense-integrated classroom, do students come to more competently and consistently construct, participate in, and contribute substantively to small-group, whole-class, and on-line discussions of chemical phenomena, especially using verbal explanations with reference to graphic representations?
- During the course of one academic term, do students demonstrate in their discussions, presentations, and assessments greater representational competence and chemical understanding of key dimensions associated with the particulate nature of matter?
- Which particular affordances or constraints of the ChemSense tools and activities promote conceptual elaboration in student discussions? How are these concepts, as developed and represented in student investigations, used in other aspects of student work?
- How are ChemSense tools and activities integrated into the chemistry curriculum and classroom? Which particular aspects of this integration provide the greatest benefits and which pose the greatest challenges for teacher practice? How do college and high school learning environments differ and potentially inform one another's learning practices?
- How do teachers model and assess representational and collaborative practice to support student representation, discourse, and understanding in this type of classroom environment? When and how do teachers explicitly guide students or explain concepts to them? How do teacher modeling and guiding practices develop over the course of one term? What types of tools and activities support teacher practice in this environment?

We are currently working with several high school chemistry teachers in Northern California to develop new curriculum modules= and to implement ChemSense in the classrooms for an extended period of time (> 4 months). Our analysis in response to our research questions will be built on rubrics for assessing representational competence and chemical understanding developed during prior ChemSense work. We also will build on rubrics for assessing collaborative groupwork developed and being refined by colleagues at SRI to assess student collaborative practice and teacher scaffolds of collaborative groupwork. Additionally, we will employ other ethnographic and discourse and conversation analytic methods successfully used by other researchers to evaluate features and functions of the classroom environment in science education. Overall, our analysis requires multiple, complementary approaches that document progressive developmental changes in, first, the organization of teaching and learning activities, and, second, student chemical representations and discourse over the duration of the academic term.

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