ChemSense is a research and development project to examine the impact of representations, chemical investigations, and discourse on chemistry learning. The 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, 1999), and knowledge building (Scardamalia & Bereiter, 1996; diSessa, 1993). ChemSense includes a set of tools (software and probeware) and curriculum activities that draw on this theory to scaffold students' learning of chemistry. These tools and activities are based on designs by curriculum integration teams of researchers, chemists, teachers, and developers, informed by learning theory and related technologies (e.g., 4M-Chem, CSILE, ESCOT), and grounded in authentic classroom use.

Our work draws on situative theory (Greeno, 1998; Brown et al., 1989; Resnick, 1988), which characterizes understanding and learning in terms of people’s participation in practices of inquiry and discourse that include interactions with others and with the material, symbolic, and technological resources in their environment. The focus of this theory is on participation in processes that construct knowledge. These processes are shaped but not determined by the constraints and affordances of interaction with physical and social systems. The affordances and constraints of physical systems—including equipment and representational systems—are those characteristics that permit or inhibit certain activities or cognitions that can be performed in the use of these systems. We extend situative theory to include the practice of scientific inquiry and the role of representations and discourse in collaborative investigations and we apply this theory to the learning of chemistry. When viewed within this theoretical context, scientific inquiry is seen as an emergent, transactional process among and between scientists and the materials at hand that include physical/chemical substances, instruments, and representations. Learning is characterized as becoming attuned to constraints and affordances of activity and becoming more centrally involved in the practices of a community.

In the chemistry laboratory, perceptual changes in chemical substances afford chemists an understanding that “something has happened,” but often this understanding is constrained by the lack of features that convey the underlying mechanisms that account for these perceptual changes. Representations, both those generated by scientists and those generated by their instruments, are among the physical systems historically constructed by the scientific community to support the understanding of chemical entities and processes. These representations, along with the discourse and meaning-making activities of the chemistry community, have resulted in significant advances in the understanding of chemical constructs, such as molecular geometry, connectivity, aggregation, state, and concentration (Coppola, 1999). The features of various representations, singularly and together, afford certain ways of thinking and talking about underlying entities and processes that advance the inquiry process and scientific understanding (Kozma, 2000; Kozma, et al., 2000).

Students, in contrast, typically do not have the representational or discourse skills that support the inquiry practices of scientists (Kozma & Russell, 1997). For example, students do not connect what they observe in the laboratory with their notions of microscopic entities and processes (Gabel, 1998). High school and even college students often have profound misconceptions of what underlies physical phenomena (Krajcik, 1991; Nakhleh, 1992). Students of all ages seem to have trouble understanding and using the scientifically accepted model that matter is made of discrete particles that are in constant motion and have empty space between them (Nakhleh, 1992). Nor are students particularly skilled in their use of chemical representations of various sorts (Kozma & Russell, 1997). Furthermore, Coleman (1998) points
out that in their discourse students often make and defend vacuous claims and rarely produce explanations or justifications for their answers.

We have developed a computer-based learning environment—the ChemSense Knowledge Building Environment (KBE)—to increase students’ chemical understanding and representational skills. With this system, we enable the use of multiple representations in the context of collaborative laboratory investigations among a community of students engaged in chemistry knowledge building. We also employ the use of instrument-generated dynamic representations, specifically real-time graphs of chemical experiments. The real-time connection between physical phenomena and their representations afford students the ability to experimentally manipulate these phenomena and observe changes in the representation. We provide students with these representational tools in the context of activity structures that support classroom social systems engaged in chemical inquiry. Our activity structure is based on Krajcik’s (Krajick et al., 1998) model of project-based investigation in which students are engaged in posing research questions, designing investigations that would address these questions, constructing apparatus and collecting data, analyzing data and drawing conclusions, and presenting findings. Our underlying hypothesis is that the use of these representational tools during the conduct of collaborative chemical investigations supports students’ convergent discourse in which they come to understand the entities and processes that underlie chemical phenomena.

In this symposium, we demonstrate the ChemSense KBE and describe the principles upon which its features and functions are based. We present findings from a high school study in which ChemSense was used for three weeks in the chemistry laboratory. Also we describe the experiences of in-service chemistry teachers as they explored ChemSense KBE to design laboratory activities. Finally, these presentations are discussed from both cognitive and pedagogical perspectives.

Paper 1
The ChemSense Learning Environment
Patricia Schank & Robert Kozma, SRI International

This paper focuses on the design of the ChemSense learning environment and includes discussion of the theoretical rationale for key design features. ChemSense is a research and development project funded by the National Science Foundation to examine the impact of representations, chemical investigations, and discourse on chemistry learning (Schank et. al, 2000). The ChemSense Knowledge Building Environment (KBE) allows students and instructors to collaborate in the investigation of chemical phenomena, build representations of these phenomena, and participate in scaffolded discourse to explain these phenomena in terms of underlying chemical mechanisms. The KBE is a virtual workspace that supports the sharing, viewing, and editing of a variety of representations, including text, images, graphs, molecule drawings, and animations. Students can annotate items, create new items that build on others’ 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 currently supported through the use of PASCO probeware and software for real-time data collection (e.g., dissolved oxygen, pH, temperature) and data display. Future implementation will take advantage of recent advances in handheld technology to enable students to collect data more flexibly and also analyze it in real time directly in the ChemSense KBE.

Our approach to curriculum activities builds on the National Science Education Standards to develop skills in inquiry, scientific discourse and explanation, and content knowledge related to structure and properties of matter and chemical reactions. 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. 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 (Coppola, 1999). 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 more traditional chemical topics, such as acid-base reaction, electrochemistry, solubility, kinetics, and thermodynamics. We currently have two complete, multi-week curriculum modules: Solubility and Soap. Geometry is the predominant dimension that governs the underlying mechanisms in Solubility, and aggregation and connectivity are predominant in Soap. These mechanisms—namely, the physical interaction of individual molecules—help underscore the drawing and animation functions of ChemSense and their usefulness in helping students communicate time-dependent chemical ideas.

In addition to a description of the design of ChemSense, our presentation of this paper will include a demonstration of the ChemSense KBE, a sample of our curricula, a general overview of our findings, and a discussion of areas for improvement and further investigation.

Paper 2
Collaborative Construction of Animations Among High School Chemistry Students
Vera Michalchik, Patty Kreikemeier, & Anders Rosenquist, SRI International

Although recent evidence indicates that it is often difficult for students to learn from viewing animations (Morrison & Tversky, 2001; Betrancourt & Tversky, 2000), the construction of animated images by students has shown some positive effects on student learning (Gobert & Clement, 1999). Our research with high-school students using the ChemSense KBE to animate various aspects of the process of solvation also shows positive effects. In this study, conducted in two general chemistry classes at an ethnically diverse high school in suburban California, thirty-eight students participated in a three-week unit on the basic principles of solubility. In addition to showing significant improvement between pre- and post-test measures, students’ work showed improvement in their ability to competently represent their chemical ideas. This finding was strongest for students who demonstrated the lowest levels of representational competence at the outset of the study. Additionally, students who created more drawings and animations using the tool showed the highest levels of improvement in our measures of key chemistry concepts and of representational competence as well.

Analysis of videotapes of two of student groups engaged in ChemSense activities suggests that creating animations helps student understanding in several important ways. First, creating an animation requires students to attend to time-sensitive and highly detailed aspects of the solvation process. Students must think through the moment-by-moment sequences of events and causality that they otherwise might fail to comprehend. Second, students must represent the steps of a particular process in relatively clear, unambiguous form. The digital media in which student animations are generated allows students to be fairly precise with their depiction of bond angles, distances between molecules, etc. Third, as students generate individual frames of the animation, their work is subject to the review and critique of peers, which encourages rich discussion regarding the conceptual implications of each decision affecting the representation. Students working in collaborative groups are faced with visible evidence of one another’s thinking as they view their artifact-in-progress, which situation readily lends itself to the type of generative discourse educators wish to see among peer learning groups. Finally, using the ChemSense tool allows students both to develop and to display their understanding within the social world of the classroom. Animations become an important part of discussions where evidence for arguments
and claims for understanding matter. Our findings overall suggest that students who create animations of chemical reactions are likely in the process to come up against the limits of their understandings, to learn from peers collaboratively working on generation of a shared artifact, and to recognize the conceptual and communicative value of their representations. For many students, an experience such as the one discussed in this paper place them in a new, generative position vis-à-vis the content matter, their peers, and the course instructor.

Presentation of this paper will include segments of videotape with relevant transcripts that exemplify student discourse while using the ChemSense tool. We will also present samples of participating students’ ChemSense animations in addition to our discussion of the design, findings, and implications of this study.

Paper 3
Issues of Scalability: The Integration of ChemSense, Teacher Preparation and Teacher Professional Development
Vickie M. Williamson, Texas A&M University
Anders Rosenquist & Patty Kreikemeier, SRI International

In addition to its use as a knowledge-building environment for novice chemistry learners, ChemSense can also be useful for teacher preparation and professional development. This paper focuses on the innovative and potentially effective uses of ChemSense by high school teachers in a professional development training session. The ChemSense KBE was featured as one of the visualizations tools used during a two week workshop titled “Structure and Properties of Matter and Chemical Reactions: Molecular Visualization,” held with sixteen in-service chemistry teachers at the Center for Teaching and Learning at Texas A&M University in July, 2001. After a brief introduction to ChemSense, the participating teachers created animations to illustrate various chemical phenomenon, including kinetics, reaction mechanisms, and equilibrium. The teachers also edited their work and exported their animations as Quicktime movies. With the exception of step-by-step instruction for exporting the animations, the teachers did not receive any formalized or in-depth training in use of the tool.

Based on their workshop experience, the teachers have started to develop curricula that involve student use of the tool, and ten of the sixteen workshop participants intend to begin using ChemSense in their classrooms in the near future. All participants in the workshop have been asked to use their newly gained skills to host a professional-development session to train other teachers in their local geographic area on use of ChemSense and other chemistry visualization tools. Survey responses regarding the ChemSense tool indicate that workshop teachers found the tool to be worthwhile and useful, and the directors of the Texas A&M program are planning to feature the ChemSense KBE again in next year’s workshop.

Prior to this workshop, the several high school studies conducted with ChemSense have been based on teacher training and curriculum development from the ChemSense research team. In this paper we describe what teachers do with the tool on their own accord, without direct guidance or pre-formed curricular ideas. Both workshop leaders and participants at Texas A&M relied on use of the ChemSense documentation and received minimal input from ChemSense researchers. This situation has allowed the research team to document how ChemSense can be adopted for use by novices without direct support. The workshop participants’ use of ChemSense tools additionally provides a unique opportunity for us to examine teacher conceptions of chemical processes and pedagogical presentation. Teacher-created animations reveal teacher strengths in understanding as well as areas of conceptual weakness that might otherwise go undetected in the course of a time-limited professional development session.

In addition to discussing teachers’ experiences in learning and developing curricula with the ChemSense tool, this paper also includes discussion of the teachers’ initial experiences using
ChemSense in their classrooms and their experiences training other chemistry teachers in their local communities.

**Discussants**
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**References**