

## Learning Chemistry by Design

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Chemistry can be a difficult subject to teach because not only is it a molecular science in which many of the concepts and processes are not visible to the eye, but students often enter the course with negative feelings toward the subject. A number of strategies have been developed to address these problems, including the following:

1. Visualizing the molecular level of matter/moving among representations.
2. Presenting content within an interesting context
3. Involving students in design activities
4. Promoting cooperative learning and active learning in the classroom
5. Addressing student misconceptions
6. Building problem solving skills
7. Engaging students in inquiry-based learning and authentic science activities

In the *ChemDiscovery* (formerly *ChemQuest*) curriculum (Agapova, Jones, & Ushakov, 2002), we designed a pedagogy for a technology-based curriculum that would incorporate all of these strategies. *ChemDiscovery* is an inquiry-oriented environment for learning chemistry (along with some topics in physics, biology, astronomy, geology, and environmental science) through the design of a virtual world. The curriculum uses linked web pages organized around a series of active learning scenarios with multiple entry points.

While completing the 10 Quests (projects) that comprise the curriculum, students design a virtual world. Each Quest has two context shells, Design of the Universe and Living in the Universe, that allow students to enter the world of chemistry from environmental, scientific, and humanistic perspectives. Once inside a Quest, students work in self-directed pairs, choosing their own starting point for each Quest and, together with their teacher, designing individual pathways through the learning environment.

Because introductory science courses are usually focused primarily on analysis and categorization, design activities are not ordinarily encountered until more advanced courses (Jones, 1999). Yet design processes play important roles in our daily lives as well as in science and engineering. The design processes at the heart of *ChemDiscovery's* pedagogy involve students in understanding needs and responsibilities; selecting raw materials; planning, designing, and predicting the properties of objects (nuclei, atoms, molecules, crystals, and larger systems); constructing the objects; and evaluating their predictions.

In addition to its motivational role, context is important for reinforcing learning. An interactive field guide shows students how the principles they are learning relate to their lives as they map their communities---not only their roads and houses, but maps of power grids, the route water takes as it flows from its source through their municipal water system, and the rock formations underlying their homes.

New types of assessments had to be developed for this approach. The assessments require students to design, model, and construct new systems. They also evaluate student ability to use comprehensive databases of information---the same type of databases used by professional scientists.

We measured the impact of *ChemDiscovery* on classroom interactions by using a series of systematic observations combined with field notes (Schoenfeld-Tacher, Madden, Pentecost, Mecklin, & Jones, 1999). We found that when *ChemDiscovery* was used in the chemistry classrooms of two high school teachers, the focus of classroom interactions shifted from a teacher-led lecture format to one in which students spent a significant amount of time working cooperatively in pairs. Teachers spent more time acting as facilitators and resources rather than as lecturers.

Because chemistry deals with the molecular level of matter, much of *ChemDiscovery* deals with modeling atoms and molecules. This work has been influenced by the research that has been conducted on learning from models and simulations (Jones, Jordan, & Stillings, 2001). A real concern of this research is how what we present to students affects their understanding and their ability to form accurate mental models. Representations of all types, whether physical models or animated simulations, can induce misconceptions.

The issues that I am struggling with and that I hope to confront with others at this conference are (1) investigating the impact of various kinds of representations on student learning, (2) finding out what characteristics make simulations and modeling activities appropriate and effective, (3) redesigning instruction to help students move from fragmented knowledge to coherent mental models, (4) finding a balance between the simplification of material that helps beginners grasp complex topics and the truth as scientists know it.

## References

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