Nakhle Group
Research Projects

Research in Chemical Education

http://www.chem.purdue.edu/nakhle/

Division of Chemical Education
Department of Chemistry
Purdue University
Research in learning theory/conceptual understanding

Some of our work probes the nature of students' conceptual understanding of chemistry concepts, with a view to improving students' understanding of and ability to use these concepts. Robin Hyder is investigating undergraduate organic students' understanding of mechanisms, using concept maps as an instructional tool to help students develop their understanding. Matt Miller is planning a study to investigate how teaching majors' specific knowledge of how to teach chemical concepts is developed. Matt Miller is also working with myself, Dr. Joe Francisco, and Dr. Susan Nurrenbern in freshman chemistry to implement a program called Collaborative for Excellence in Teacher Preparation (CETP). This is a funded program which is being implemented throughout the School of Science. In these courses we are training the TA's to lead the students in group work, and we also are training the TA's to develop concept maps with their students in order to help these students 'make the connections' in chemistry. Students' understanding is assessed with concept map quizzes and paired questions on exams. Rebecca Jardine is investigating preservice teachers' understandings of the nature of science.

Research in learning with technology

My group is also very interested in how technology, interpreted broadly, affects students' understanding of chemical concepts. Eric Malina is exploring how students are learning in the lab with the instruments provided by the Purdue Instrument Van. John Polles is investigating students' perceptions of the laboratory environment in general. Bill Donovan is looking at how use of the World Wide Web can impact students' learning in freshman chemistry courses.
John Polles

The Role of the Laboratory in the Learning of Science: What About the Learner's View?

Background: In the current paradigm of teaching science, there is widespread support for the value of the laboratory, but little agreement on the specifics. Yet, one should question the basis for the widespread support. In a major, 166-page review of the literature covering the role of the laboratory in science teaching, Blosser (1980) came to the conclusion that most of the literature was opinion-based, with most of the authors assuming that the necessity of laboratory work was obvious.

Research Proposal: My immediate research goal is to examine the role and effectiveness of the laboratory in the learning of science. Most of the research into the effectiveness of the laboratory is concerned with trying to fix the shortcomings of the accepted laboratory experience. I believe we need to explore the laboratory experience with a primary, bottom-up focus. To consider the value of the laboratory in the learning of science, I propose that the first step be to explore the laboratory experience from the students' view.

In order to convincingly establish the value of the laboratory experience at the freshman level, we need to look at the psychomotor, cognitive, and affective domains. The study will be longitudinal: a positive (or negative) effect of the laboratory experience may not manifest itself in the short term. I am particularly drawn to the affective domain question: What role(s) does the lab experience play in developing students’ values toward chemistry or science?

The first direction of the research will be a qualitative design in order to explore the laboratory climate from the learners’ view. The research will be a phenomenological inquiry, concerned with the internal meaning structures of lived experiences. I am interested in the participants' experiences and derived meaning from the laboratory. This framework centers around individuals' experiences and interpretations, the essence of the shared experiences.
This research explores the 'how, why, and what' students are learning using instruments in the laboratory based on 1) Kozma's ideas of learning from various media, 2) Hutchins' model of distributed cognition, and 3) my own previous research on the impact of scientific instruments on student learning and attitudes towards science. Experiments involving scientific instruments were chosen as a focus for this study because of the rich chemistry involved, the interactive nature of using instruments in the laboratory, and the practical applications associated with these instruments. Instruments are an integral part of modern society, from automobile repair to modern scientific research, thus a better understanding of the impact instruments have on student learning and motivation could help educators determine when and how students should be exposed to scientific instruments. Therefore, I will investigate the impact of analytical instruments on advanced chemistry student learning of chemistry concepts.

Background Literature

During my master's research (Malina, 1999), I noticed that the use of scientific instruments seemed to increase student motivation, and that students perceived instruments as aiding in their learning of chemistry concepts. However, my masters' research did not focus on discovering how and/or what chemistry concepts were actually being learned. Therefore, this study is a natural extension of my previous research.

A search of the previous research in this area revealed that very little work has been done on how students learn from instruments. However, I discovered some research on media that could be helpful in the study of learning from scientific instruments. Kozma (1991) analyzed the various characteristics of such media as books, television, and computers for their impact on student learning. He argued that each type of media has unique capabilities that can influence student learning resulting in more or different learning from one media to the next. Kozma proposed that different types of media can be categorized by their characteristic symbol systems and processing capabilities. He reached two conclusions. First, he noted that some students would learn regardless of the type of medium used to present the material. Second, he found that other students could benefit from the unique capabilities of the medium if teaching strategies also took advantage of these capabilities.

Ullmer (1994) supported Kozma's conclusions and proposed a new focus for research into the potential benefits and drawback of various media. Ullmer proposed that a full understanding of learning with media requires documenting not only the interactions of students with the media, but also the environment in which the student-media interactions take place. The documentation should not only describe the media's learning and logistical benefits, but also describe any dysfunctional effects involving motivation, communication, ergonomics, or social interactions. All aspects of media's influence on learners need to be taken into account when evaluating the benefits of the media.

I agree with Ullmer and Kozma. Learning is influenced by both the method of instruction and environment in which it takes place, and thorough research into these factors need to be performed if media is to be used effectively in the classroom. Like different forms of media, scientific instruments, when compared to traditional laboratory activities, could possess unique characteristics that could aid in the students in developing their understanding of chemistry concepts.

Research Questions

1) What are the characteristics of specific scientific instruments that have implications for learning?
2) How student understanding of chemistry concepts is impacted by their interaction with instruments?
Assessing Student Understanding of General Chemistry with Concept Mapping

Joseph S. Francisco, Mary B. Nakhleh, Susan C. Nurrenbern, Matthew L. Miller

The ability of students to construct connections between chemistry concepts is of major concern to educators. This study, conducted in a large enrollment introductory chemistry course, sought to investigate whether concept maps constructed by students helped develop increased understanding of chemical concepts. Three cycles of research, implemented during three different semesters, used concept maps in a variety of situations to enhance student understanding. Cycle One utilized concept maps as homework assignments and as a post-laboratory assignment. Cycle Two utilized concept maps as homework assignments and as an assessment tool on weekly quizzes. Finally, Cycle Three used concept maps as group activities and as an optional assessment tool.

Results indicated that concept maps provided an excellent tool for students to generate meaningful connections between chemical concepts. Evidence is shown that concept maps can be used by students, professors, and teaching assistants to provide information about a student’s conceptual understanding. Additional evidence is shown that a student’s conceptual understanding does affect the ability of that student to answer algorithmic questions. A grading rubric for assessing student concept maps is also presented. Finally, several issues regarding one, the use of concept maps as assessment tools, and two, the attitudes students and teaching assistants toward the instructional use of concept maps are discussed.

Enriching Pedagogical Content Knowledge of Prospective Chemistry Teachers: How Can the Science Methods Course Help?

The quality of chemistry teacher preparation continues to be a major concern for chemistry educators. This study investigated how prospective chemistry teachers (n=6) constructed pedagogical content knowledge (PCK) during a science teacher methods course. Of specific interest were the types of interactions that enhanced the PCK. For each participant, we first collected concept maps, concept map layover lesson plans (COMALLPs), interviews, videotapes of microteaching, written critique forms from peers and the course instructor, exams, and reflection journals. The student constructed concept map represented his/her content knowledge for a chosen chemistry topic. The student constructed COMALLPs explained the individual student teacher’s proposed pedagogy for the chosen chemistry topic and expressed the student teacher’s concerns regarding the teaching of that topic. Interviews were conducted to obtain the participants’ view of how specific interactions that occurred during the methods course affected their knowledge structures represented by concept maps and COMALLPs. Then, videotapes, written critiques, exams, and journal entries were analyzed for evidence of the interactions participants identified as affecting their PCK. Case studies were constructed from the perspective of each prospective chemistry teacher which described the interactions that occurred and how these interactions resulted in PCK enhancement.

The identification of interactions that enhance PCK is important in the continual improvement of chemistry teacher preparation. The knowledge of how these interactions guide prospective teachers to construct PCK will help teacher educators create learning environments favorable to the development of PCK in prospective chemistry teachers.
Many chemistry educators have turned to the World Wide Web to provide their students with access to representations of chemical phenomena that are difficult to present in traditional ways. Dr. John Nash and Dr. William Robinson have created web-based tutorial materials for visualization and problem solving for five general chemistry topics. These tutorial materials include static, animated, and user-manipulable representations of molecules and chemical processes. We are investigating the perceived and measurable effects of using these web-based representations on student understanding of chemistry concepts.

**Research Questions:**
- Why do students choose to use or not use these Web-based materials?
- How do students perceive their understanding of chemistry concepts to be affected by use of the Web-based representations?
- How might student understanding of chemistry concepts be affected by the use of the Web-based representations?

Students who used and did not use the tutorial help page will be interviewed about the nature of their experience with the Web and how their understanding was affected. Students will be asked to discuss relevant chemistry concepts and draw a concept map of a chemistry topic. Concept maps and student responses to the chemistry content questions will be compared across Web site users and nonusers to determine if and how student understanding might be affected by Web site use.

The pilot study, performed in 1999, suggested that students may be attracted to the web-based materials because they feel that they need help with chemistry and that the web site offers visualization and representations that are difficult to see in a book. The students who did not use the web site appeared to have a “better” understanding of chemistry than students who did use the web site, however. This result is consistent with other research our group has done about using the web to learn chemistry. Our speculation is that weaker students may be attracted to the web site for extra help or exposure. Another interesting result is that where differences between genders exist in responses to survey question, female students responded more positively than male students with regard to attitude toward using the web site.
Robin Hyder
Explaining the Mechanics of Problem-Solving with the Use of Concept Maps and “Think-Aloud” Problem-Solving Protocols Among Students in Sophomore Organic Chemistry

Background: Among the numerous instructional approaches available to help students develop a structural understanding of novel information, concept maps have been shown to be a useful tool in a variety of knowledge domains by providing the learner with opportunities to structure concepts in a meaningful way. In the realm of sophomore organic chemistry, however, the potential utility of concept maps, as a tool to develop problem-solving skills, has yet to be assessed. The “think-aloud” problem solving protocol, which has been an active topic of research lately, is aimed to disambiguate the thought processing carried out by the students. Therefore, this proposed investigation offers a reasonable contribution to the literature in the area. It invokes the use of concept maps and “think aloud” protocols to address the issue of thought processing, and how they pertain to performance in solving mechanism problems in sophomore organic chemistry.

Focus: This investigation seeks to establish relationships in the ways that problem-solving success of students in introductory organic chemistry can be improved by concept mapping skills. The expected end-result of this study is to develop an understanding of how student performance in solving mechanism problems in electrophilic addition reactions of alkenes, using concept maps, changes their cognitive structure thereby enhancing their understanding of the mechanisms.

Specific Procedures: Subjects will be selected from a pool of student volunteers from CHM 257, a single-semester introductory organic chemistry course for agriculture and health-science majors. The students will be paired randomly into either the concept map group or the discussion group. The subjects will be called in for five separate sessions of group activities, spread throughout the semester. The first meeting will be an informational session. In each of the middle three sessions, the concept map group will be asked to establish links among the given terms in their concept maps. The students in the discussion group will be asked to discuss the meanings and relatedness of all the given terms in all four sessions. They will, then, be videotaped while they solve mechanisms. From the recorded transcripts, episodic graphs will be generated for each group to account for the differences in the thought processes of the students. Calling the groups back for a third and fourth session will involve constructing concept maps for the same electrophilic addition reaction terms, as well as solving mechanism problems of increasing difficulty, to assess the notion that their problem-solving skills are indeed improving. In the fifth session, the students will be interviewed to rationalize their concept map constructions in the earlier meetings.
Rebecca Jardine

Investigating Preservice Teachers’ Understanding of the Nature of Science

I am the newest member to the group. My undergraduate education integrated chemistry and education making Purdue a perfect place to continue my education. I began here in the fall of 1999 and so I am just beginning research for my masters. My interests are in secondary science education. Not only am I interested in furthering students’ understanding of chemistry, but also in science teacher education.

Although I am at the beginnings stages of my research, I have started to get things underway. My research is a look at what pre-service teachers know and understand about the nature of science. The National Science Education Standards list eight criteria for students K-12 to be scientifically literate. One content standard or criteria is that students understand the nature of science. This standard is often neglected in teacher education programs; therefore teachers are not prepared to share this knowledge with their students. I plan to uncover what future teachers know about the nature of science through interviews and the study of their lesson plans.
For More Information

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