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NSF Highlights

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Sparky IntroChem: A Student-Oriented Introductory Chemistry Course

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Reform of introductory chemistry has been the topic of considerable interest in the *Journal of Chemical Education (1).* Several recent reform initiatives have attempted to improve the teaching/learning process in general chemistry by shifting the focus of the classroom from the teacher to the student *(1).* Some of these approaches include: process workshops, in which students work in self-managed teams on discovery-based activities *(2, 3);* a software program (LUCID) to allow the use of interactive learning and tool kits in process workshops *(1);* topical modules to increase interest while promoting cooperative learning *(4);* guided-inquiry activities in groups *(5);* ConcepTests, which are thought-provoking questions or problems presented in lecture to evaluate learning; peer-led workshops, in which successful course graduates lead small groups of students in discussion and problem-solving *(6);* the implementation of WWW discussion boards, which allow student-teacher and student-student communication at any time *(7);* and inquiry-based, discovery-based, and problem-based laboratories *(8).*

The Introductory Chemistry (IntroChem) course (Chemistry 132) at Western Carolina University (WCU) has the highest enrollment of any course in the department, typically 300 students per year. This course is required as a terminal introductory chemistry course for a number of majors, including health sciences (e.g., nursing, nutrition), natural resources management, and environmental health. Science majors who have not had high school chemistry also enroll to obtain the necessary background for Advanced General Chemistry. The course has traditionally been taught in large lecture sections (three hours per week) with a two-hour laboratory.

With support from the National Science Foundation, we have incorporated some of the student-oriented approaches listed above into our IntroChem course to improve student learning in (1) mathematical problem-solving skills, including interpretation of graphical and tabular data; (2) understanding and using concepts; (3) scientific reasoning; and (4) development of positive attitudes towards science. The goal has been to develop an engaging, student-centered course. The word "sparky" means lively, and hence we have named the course Sparky IntroChem. In order to achieve these goals, we have developed innovative modules, laboratory experiments, and workshop materials.

Course Structure

Sparky IntroChem is a four-credit course consisting of 3 hours of lecture, 1 hour of workshop, and 2 hours of laboratory per week. We use a conventional textbook *(9),* and give three, one-hour examinations and a final exam, which is 50% of the course grade. We limit the size of the lecture sections to a maximum of 60 students. Our university is fortunate to have a tutoring center (the "CAT Center") that provides free tutoring to students. Students receive five bonus points on an exam (but no more than five points) for attending at least one of the tutoring sessions. We have found that many students initially plan to attend tutoring once for the additional points, and find it so useful that they become regular attendees. Typically half of the students attend at least one tutoring session before an exam.

Students are required to do two projects during the semester with their workshop group (see p 138), which comprise 20% of their course grade. The projects consist of an oral presentation and a poster presentation related to applications of chemistry (e.g., gases). Students have selected a wide variety of topics, including welding, chemical demonstrations, medical applications, and environmental issues. Students usually do an excellent job, and they gain an appreciation of the relevance of chemistry to practical applications. Students are required to select a topic two weeks before the presentation date; we have found it helpful to have them meet in these groups for approximately 15 minutes to select a topic during the lecture, just before the topic due date.

The laboratory counts for 20% of the course grade (see below for details). Homework and class participation compose 5% of the course grade. We have found it necessary to collect and grade homework in order to ensure it is completed by a reasonable fraction of the students. The remaining 5% of the grade is based upon attendance at the workshops (see below). We require attendance, particularly at the beginning of the course, to encourage participation.

Modules

During the development of Sparky IntroChem, we explored the use of modules as a focus of classroom discussion. Our modules, like many of those previously developed *(4),* focus upon issues of societal importance, but we have chosen to emphasize issues of local importance. We modified two modules developed by others and developed two of our own.

One of the major deficiencies we have observed in our IntroChem students is a weak background in mathematics, including problem-solving skills and the use of technology (calculators, the interpretation of graphical and tabular data). In addition, many students with more background have difficulty applying mathemtics to scientific problems. It is clearly essential to foster mathematical literacy (numeracy), including the use of formulas, scientific notation, and the metric system, for these students to understand science. We devel-

Laboratory Experiments for Sparky IntroChem *(11)*

Chemistry Experiment	Title
132.L1	A Shape Memory Alloy, Nitinol
132.L2	Physical and Chemical Changes
132.L3	Chemical Reactions—Part 1
132.L4	Chemical Reactions—Part 2
132.L5	Graphing Relationships
132.L6	Mass/Volume Relationships and Direct Proportionalities
132.L7	Isolation of Caffeine from Tea
132.L8	Simplest Formula of Magnesium Oxide
132.L9	Red Cabbage: A Vegetable pH Indicator
132.L10	Recycling Your Can: Making Alum
132.L11	Reaction Ratio of Magnesium and Hydrochloric Acid
132.L12	How Effective Is Your Antacid?

Peer-led Workshops for Sparky IntroChem *(11)*

1	Introduction to Workshop[a]
2	Using Your Calculator and Algebraic Solutions[b]
3	Unit Conversion by Dimensional Analysis[b]
4	Graphing[a]
5	Atoms and Subatomic Structure[b]
6	Organization of Elements—The Periodic Table[b]
7	Building Atoms with Quantum Leaps: Electron Configuration[b]
8	Compounds and Their Reactions[a]
9	Covalent Bonding: Lewis Structures[b]
10	The Structure of Molecules: VSEPR[b]
11	The Mole Concept[a]
12	Introduction to Stoichiometry[b]
13	Gases: Nature, Laws, and Applications[b]
14	Solutions[b]
15	Ionic Compounds and Their Reactions[a]
16	Acids and Bases[b]
17	Review for the Final Exam[a]

[a] Developed as part of this project; available at *(11)*
[b] Adapted from Gosser, et al. *(16)*

oped a module focusing upon mathematical problem solving that involves gold *(10),* which was once mined in western North Carolina. We present the properties of gold to introduce the metric system, scientific notation, and simple problem solving. ConcepTest questions are employed in the classroom to assess student progress. For example, the students calculate the total mass of gold in the earth. The module concludes with a discussion of the nuclear model of the atom, including discussion of isotopes. It is available at our Web site *(11).*

In the second section of the course we employed a module developed by Stacy and Molinaro that focused on airbags *(12)* with modifications to better fit the WCU student population. The theme of the module considers the design of a practical airbag. We employed this module to develop the mole concept and to consider properties of gases, gas relationships (e.g., ideal gas law), and gas stoichiometry. It provides a practical application through which important chemical properties may be introduced.

We have developed our own module *(11)* that focuses on pulp and paper chemistry. It includes wood's structure and chemical composition, paper production, the production of board and structural materials, and the conversion of wood to energy, fuels, and chemicals *(13, 14).* Chemical concepts that are considered include the quantum mechanical model of the atom, electron configuration, Lewis structures, VSEPR, and basic organic functional groups.

The final section of the course employed a module on water treatment developed by Kegley and coworkers *(15)* that we altered to address the background of WCU students. Water treatment was employed to consider aqueous inorganic chemistry, solution preparation, and acids and bases.

Although we found the modules to be of interest to many students, they led to problems with the organization of the course. We found it was necessary to consider topics in what appeared to students to be a haphazard order. This was particularly confusing with respect to the textbook. Several of our faculty members were also uncomfortable with this as well, and so we have abandoned the use of modules in the course. However, we continue to use them as sources of problems and discussion topics.

Laboratory Experiments

One of the goals of our project is to develop exciting, hands-on activities for Sparky IntroChem. The laboratory experiments were designed to help students develop scientific reasoning skills. These labs employ relatively few hazardous chemicals, with a few exceptions addressed in their student orientation. A list of laboratory experiments for Sparky IntroChem is given in the list above, and the complete experiments are available at our Web site *(11)*.

Workshop Materials

The Peer-Led Team Learning Workshop Model is a method for teaching scientific disciplines that has been developed by a team of faculty and learning specialists from a variety of colleges and universities *(6, 16).* In the Workshop Model, students who have done well in class become Workshop Leaders, who then lead small groups of four to six students through chemistry problem sets. These peer-led groups, which meet weekly to work on carefully structured problems, provide a supportive environment that helps each student build understanding of chemistry and other disciplines.

For Sparky IntroChem, 11 sets of workshop materials have been adapted from the developers of peer-led workshops *(16);* an additional six workshops have been developed by us. A complete list of workshops employed in Sparky IntroChem is given in the list above, and the workshops we developed are available at our Web site *(11)*.

The workshops have proven to be a very successful addition to this course. Interviews, conducted as part of the project evaluation, as well as student comments have been very positive. Surveys indicated that more than 70% of students felt workshops had a positive impact on learning, and more than 80% felt workshops were important or very important in grasping difficult concepts. Workshops are now an established part of Sparky IntroChem, and we are considering incorporating them in other courses. We would also like to emphasize that workshops are also extremely beneficial to the undergraduate and graduate instructors. Almost all of the leaders agree that this responsibility has increased their knowledge and confidence in chemistry.

Conclusions

In conclusion, we have converted the Introductory Chemistry course at WCU from the traditional instructor-oriented model to a student-oriented model using previously developed approaches. We have found replacing some in-class examinations with projects helps students discover the relevance of chemistry. It has also been beneficial to encourage students to attend tutoring sessions provided by the university. Lastly, we have found that peer-led workshops are highly beneficial to both the students and the student instructors in Sparky IntroChem. However, modules were met with skepticism due to the abrupt changes from one topic to another.

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