CHEMISTRY

Development of a Materials-Oriented General Chemistry Course

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Chemistry

A materials-oriented approach to chemistry is being developed through the preparation of course materials entitled "Teaching General Chemistry: A Materials Science Companion", by an ad hoc committee of two dozen leading chemistry researchers and teachers. Consisting of text, problem sets, model kits, software, videotapes, demonstration and laboratory experiments, the "Companion" was published by the American Chemical Society in 1993. The "Companion" demonstrates how virtually every topic typically covered in introductory chemistry courses can be illustrated with solids such as semiconductors, metals, superconductors, polymers, and ceramics. The project focuses both on innovation—the completion of material for the "Companion"—and on change—the implementation of a national strategy for assimilating materials chemistry into introductory chemistry courses. Strategies for effecting change include national testing of the "Companion" at over two dozen volunteering college test sites (more than 15,000 students); development of modules based on the "Companion" and their use in workshops for college and pre-college teachers; and critical evaluation of the instructional materials by teachers and students through direct feedback and measures of student interest and performance. The "Companion" and supporting activities will revitalize general chemistry courses, enhance the scientific literacy of students and teachers, and increase the number and diversity of high-quality students electing to pursue careers as chemists, chemistry teachers, scientists and engineers. Some of the materials in the "Companion" can also be used in other introductory science and engineering courses. The steps involved in organizing and implementing this project are being summarized and disseminated.

Development of Computer Graphic Visualization Aids for the Undergraduate Chemistry Curriculum

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DUE-9354453
FY 1994 $100,000
FY 1995 $ 100,000
Chemistry

This project is developing high-end, workstation-quality computer graphics to aid in the visualization of concepts taught throughout an undergraduate chemistry curriculum. The goal of the work is to focus on visual presentations and real-time visual manipulations of a variety of concepts that are included in the current chemistry curriculum. Specific projects include three-dimensional animation sequences of atomic and molecular orbitals, three-dimensional views of polymer structure and stereochemistry, videos that introduce basic stereochemical concepts in organic chemistry, and animated sequences of crystal structures and Miller index planes. Additional projects include other basic organic transformations, periodic trends, and hybridization. The specific goals of this project are to develop materials that can be used in courses throughout the United States and can be readily distributed on computer disks, laser disks, and videotapes, so

that the efforts of this project can have a broad impact on the national undergraduate and high school chemistry curriculum.

Introduction of Modern Instrumentation in the First Two Years of Chemistry: The Iowa Chemistry Curriculum Network (IACCN)

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DUE-9455646
FY 1995 $ 260,621
Chemistry

This project is researching, developing, and incorporating three modular instruct ional resources on modern instrumentation into the first two years of college chemistry. The modules contain instrumentation-oriented components dealing with current real-world topics, group projects, updated teaching methods, student learning assessments, emphasis on conceptual thinking, interactive multimedia, and exploratory laboratory experiments. Development of interactive, multimedia computer programs that simulate the operations of the FT-IR, and FT-NMR spectrometers, from sample handling to data acquisition and workup, is being developed in collaboration with Engineering Animation, Inc. A UV-VIS multimedia simulation has already been developed at the University of California at San Diego. A consortium of Iowa's 15 community colleges, three public universities, and four private colleges are collaborating on all aspects of the project through long-distance video conferences on Iowa's fiber-optics communication network and at annual summer workshops. This project is enabling students and faculty in the entire state of Iowa to have facile access to modern instrumentation (UV-VIS, FT-IR and FT- NMR) via computer simulations. Iowa State University is serving as a clearinghouse for running actual chemical samples submitted by students of the participating institutions. The samples are being run on instruments at Iowa State University, and the spectra are being made available to the students and faculty from the community colleges and private colleges over the Internet (via anon ftp, the World Wide Web, or by e-mail) as digital files or graphic images. This project is providing new curriculum enhancements and developments to four-year institutions and all community colleges in the state of Iowa.

Building Conceptual Frameworks with Synchronized Multiple Visualizations

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Chemistry

A common dilemma of first-year college chemistry is that the needs of diverse student populations are not being met by the traditional instructor-focused classroom. At College of DuPage, Oakland Community College, and Oakland University, this diversity includes ethnicity, age distribution, aptitude, science background, and learning styles. In this project, classroom time

is being used to help students develop conceptual understandings that incorporate the ability to view phenomena from multiple perspectives. Classroom activities stress active learning and scientific exploration. Topics and methods are used that reflect contemporary science integrated with the personal experiences and interests of students. Interactive-multimedia materials, showing synchronized multiple representations of chemical species and phenomena, are being developed and used in classrooms and by groups of students. A sense of ownership of new materials and commitment to their use is being developed by involving faculty, from all institutions, in their selection, design, development and evaluation. Student versions encourage group learning and exploration. Training workshops are aimed at assisting faculty in implementing the multimedia materials in manners that promote more active learning environments. Evaluations assess: (1) changes in classroom pedagogy, (2) achievement gains of students, and (3) changes in students' attitudes toward science. Project products will be nine multimedia modules, student versions of each module, training workshops and their support materials, assessment materials and research analyses of the effectiveness of all products.

Biologically-Relevant Chemistry in the Freshman Laboratory

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DUE-9455418
FY 1995 $ 190,000
Chemistry

In this project, which is an innovative approach to teaching the freshma n chemistry laboratory, students are exposed to a variety of chemical principles in the context of biologically-relevant chemistry. Large numbers of students taking freshman chemistry (upwards of 60%) are pursuing careers in the biological sciences and/or medicine. These students are being shown the relevance of chemistry in understanding biological systems by engaging them in authentic scientific inquiry. The program is module-based, where each module focuses on a specific question that the students must answer about a biologically-relevant problem. Each laboratory module is designed as an in-depth study lasting three to four weeks. "A guided-discovery method" of teaching the course is employed, and teamwork and decision-making are emphasized. Computer pre-labs are used to ensure that the students are confident in what they need to do when they enter the laboratory, and interactive videos help them to grasp difficult concepts. Novel computer-based examinations are being developed and tested. The topics of four of the modules include: (1) The Chemistry of the Stomach; (2) Skin Cancer; (3) Lead Poisoning; and (4) Blood Chemistry. The fifth module is designed to expose the undergraduate students to science teaching in the local primary and secondary schools. Each college student observes and participates in a K-12 science classroom, reads articles in science education journals, works with a science teacher in a local school, designs and teaches a laboratory-based project for the K-12 classroom, and participates in discussions and evaluations about the science lesson that has been taught and the conclusions that have been reached about the teaching and learning of science.

Development and Evaluation of Internet-Based Hypermedia Chemistry Tutorials

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FY 1995 $ 80,000
Chemistry

The goal of this project is to develop and evaluate Internet-ba sed hypermedia tutorials for undergraduate chemistry courses. The specific objectives are: (1) to develop hypermedia resources that increase the effectiveness and efficiency of student learning and retention, (2) to evaluate and refine hypermedia designs for maximum student use and efficacy, and (3) to evaluate the accessibility of hypermedia educational materials via the Internet for students and educators inside and outside the university. The main advantage of hypermedia educational materials is the ability to link a topic to related and/or remedial material. Having immediate, in-context remedial help will improve the effectiveness and efficiency of a student's study time, and will also reinforce the understanding of basic concepts. The links themselves illustrate the interrelatedness of different topics and the importance of basic principles. This project is expanding the current hypermedia tutorial for instrumental analysis to sophomore-level analytical chemistry and freshman-level general chemistry classes. The chemistry tutorials are viewed with NCSA Mosaic, which is an Internet-based hypermedia browser. It is a multimedia viewing tool with versions for UNIX, Windows, and Macintosh operating systems. Since this project is accessible world-wide via the Internet, it will provide an educational resource for undergraduate chemistry students; K-12, vocational, and college-level educators; and for the public at large. The hypermedia design and Internet access concepts that are developed by evaluating and refining this project will facilitate the creation and distribution of effective hypermedia resources for science education in chemistry and other disciplines.

Molecular Modeling for the Introductory Organic Chemistry Courses

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DUE-9354596
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Chemistry

The project is developing molecular modeling/computational chemistry experiments for use in first-year organic chemistry courses. Computational chemistry, rapidly becoming an almost routine tool for academic and industrial chemists, allows students to investigate efficiently a variety of molecular attributes including conformational stability, preferred bond angles and lengths, energies of reaction, and reaction pathways. Results provide rationalization of known data, or predictions subject to verification. These benefits accrue only with the aid of a high-quality, integrated visualization environment, a feature central to this project. These experiments are being introduced as hands-on exercises to 240-280 organic laboratory students per year, including chemistry and biochemistry majors and most pre-health profession students. Each year approximately 500 students in the organic chemistry lecture course are being shown the numerical and pictorial results of a variety of pertinent computations. This group of students includes both biology majors and those training for pre-college science teaching careers.

Cooperative Organic Laboratories

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Chemistry

Most traditional organic chemistry laboratories tend to be of the cookbook type. That is, students learn laboratory techniques and then use them to synthesize a given compound in a prescribed manner with a recipe. There is growing unease within the chemical education community about the pedagogical value of such laboratories. In this project the organic laboratory course is being modified by building on the known strengths of the previously-developed cooperative general chemistry laboratory courses. Students work in groups on open ended projects instead of one lab period exercises. Instead of learning a technique as an end in itself, techniques are being learned as a means to an end. Over the course of the semester, students apply their problem-solving skills to projects approximating the research process as closely as possible. The students also use both their written and oral communication skills to plan, critique, and evaluate their experiments. A number of resource materials are being developed including a multimedia program that incorporates video and text so that students can access information in the laboratory, and a laboratory manual that contains a database of typical experimental conditions and work-up procedures in addition to descriptions of techniques. This new lab format will have a significant impact on how students learn organic chemistry and will be particularly beneficial to women. The principal value of this project lies in its application to all organic students, in the expected improved performance and higher retention rates for women, and in its adaptability to other situations.

The Language of Chemistry: Introductory Chemistry Based on the Study of Problems at the Interface Between Chemistry and Biology

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Chemistry

This project is developing a new introductory course, *The Language of Chemistry*, intended primarily for non-chemistry majors. The immediate challenge is to provide an attractive course that students majoring in areas such as the social sciences and the humanities will elect to help fulfill a distribution requirement. The course illustrates how chemists study problems involving chemical interactions in nature. Among the cases likely to be included for study are the chemistry of gamete attractants; the female pheromone of the silkworm moth; quinine, antimalarials, and synthetic dyes; penicillin; and taxol. Basic concepts in general chemistry and organic chemistry are being developed as required. The methods of analyzing problems are being emphasized instead of the memorization of specific results or formulas. Students should gain an understanding of subjects as diverse as chromatography and other purification techniques, spectroscopy, molecular formulas, molecular structures (and how chemical and physical methods

establish them), stereochemistry, atomic structure, the periodic table, chemical bonding, functional groups, Avogadro's number, and the importance of synthesis. Students, working in small groups, prepare and present short reports on chemical topics, based on library research. The project staff is working with colleagues in the science education department to develop and evaluate the course and related materials.

Transforming Traditional Quantitative Analysis into a Course in Modern Analytical Science

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Chemistry

This curriculum development project transforms traditional sophomore quantitative analysis into a course on modern analytical science. The project is developing a course that emulates the working environment of a modern commercial analytical laboratory. The new lab work reflects a commitment to addressing organic, biological, and environmental studies, in place of much of the traditional emphasis on simple inorganic systems. The types of investigations include: separations science (mixture analysis); multi-element and trace analysis; and combined physical and chemical characterization. Pervading all of this is a laboratory structure based on Federal Good Laboratory Practice Guidelines, where students are responsible for calibration, certification, and documentation. The objectives of this project are: (1) to conduct a realistic experiment in transportability of the restructured sophomore quantitative course; and (2) to produce a laboratory manual which is flexible enough to be useful even at institutions with limited resources. A small but diverse group of interested academic institutions has been enlisted to test transportability at their respective campuses. These schools will also provide feedback regarding laboratory revisions to help accommodate the wide diversity of academic resources. The project was initiated at a summer workshop in 1995 at San Jose State University for all participating faculty. This event will be repeated through 1997, with a viable laboratory manual as the ultimate product.

Improving Student Instrumentation Skills with Pre- and Post-Lab Computer Simulations

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Chemistry

Proper use of instruments is integral to the physical and life sciences, yet many students never become confident or even comfortable operators because of limits on laboratory time and instrument availability. To introduce principles and procedures before laboratory exercises and to

reinforce key experimental ideas after laboratories, a series of interactive computer simulations of laboratory devices and accompanying text materials is being developed. These simulations allow students to explore instrument concepts at their own pace, alone, or in groups. Using an icon-based simulation engine/environment which embodies a block diagram approach, realistic and sophisticated simulations (with on-line help, text and graphical output, and animation) can be created much more rapidly than those written in higher-level languages and can be easily tailored to specific courses and audiences. The exercises promote logical thinking, active learning, and the formulation and testing of hypotheses.

Development of Collaborative, Computer-Networked Laboratories in General Chemistry

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Chemistry

This project provides students with realistic experience in the laboratory of the scientific process and skills for solving real-life problems. The project extends a three-year pilot project that uses collaborative computer-based learning to meet the above goals. Student groups explore the same general problem, but each group uses different reagents. A networked computer system (CoLABnet) is used to collect, pool, and summarize the largely qualitative class data. The pooled data allow the students to examine more parameters with better accuracy than would individual data. The discovery of trends is facilitated by presenting students with multiple instances of the same phenomenon. Groups use commercial graphing software and communicate their findings during a post-lab discussion. Preliminary data from the pilot project indicate that student learning and responses are improved by the new methods. The project evaluates the impact on student learning, evaluates and optimizes the design and implementation of software, develops new software around a commercial database program, and develops and implements a training and support system for TAs. As part of the TA training process, newly developed videotapes dealing with instructional techniques relevant to the collaborative learning classroom are used.

The Integration of Molecular Modeling Across the Chemistry Curriculum as a Tool for Understanding Chemical Structures and for Developing Critical-Thinking Skills

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Chemistry

Quantitative structure-activity relationships (QSAR) are of concern in many areas of chemistry where the search for specific properties is of particular interest. Because of their importance, structure-property relationships are taught at every level of the undergraduate curriculum. Although “structure” plays a crucial role in chemistry, it is typically portrayed in

undergraduate programs using two-dimensional line figures or hard "ball-and-stick" models. Using the computer to display structure provides an alternative approach. Images can be displayed in three-dimensional space, and variations can be presented to show such properties as charge, isodensity surfaces, or orbitals. However, unless curricular materials are appropriate for a student's stage of development, the use of computer modeling techniques could lead to misconceptions about the nature of the forces that lead to observed structures.

The goal of this project is to develop materials that integrate molecular modeling across the chemistry curriculum. The project plan involves students' use of molecular modeling to learn chemistry while developing thinking skills from simple analysis and comparison through inference, and addresses synthesis of results and evaluation of findings. HYPERCHEM software has been selected for the project. The exercises do not replace a "hands-on" laboratory program. Rather, they are team projects or individual assignments that are done during "open lab" times in the department's computer laboratory. The project begins with in-house faculty development conducted by the project director and a consultant. The faculty also upgrade their expertise by attending an external meeting or conference related to the project. They then work together to develop a coherent set of exercises that build on student background at each level of the undergraduate program. Current chemistry majors are involved in testing the exercises prior to use in each course. These students are hired to serve as laboratory aides during the open computer laboratory hours.

An evaluation process for the project has been designed to establish that the curricular materials are fulfilling the intended outcomes and to determine what additional capabilities of the software can be added in the future. Formative evaluation includes both qualitative and statistical data collected throughout the project and used to modify plans as needed. An external evaluator is being engaged to complete a summative evaluation.

This project focuses primarily on courses taken by first- and second-year chemistry and biology majors and includes selected upper-division courses in which the technique has significant applications. Non-science-majors are also learning to model simple molecules—they are learning science by "doing what scientists do."

This approach is significant in that it calls for integration of modeling techniques across the major program, rather than for use in isolated experiments and exercises developed and used by individual faculty members. It provides a creative means for developing thinking skills and for fostering teamwork. Results are being shared with faculty members in other science departments at Clarke College and at two other local colleges. Project results will be disseminated externally by publication and presentations at professional meetings.

Chemistry Curriculum Innovations: An Integrated Curriculum for First- and Second-Year Chemistry Courses

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Chemistry

A curricular innovation is being implemented to address the problems of the traditional sequence of a year of general chemistry followed by a year of organic chemistry. These problems include: an artificial segregation of inorganic and organic chemical concepts; a large emphasis on

quantitative skills one year and qualitative skills the other; introduction of theory prior to its empirical basis and unrelated to laboratory experience; and a perception by students that chemistry is disjointed, lacking both continuity in its presentation and relevance in its application.

There are three critical components to this renovation of the curriculum: (1) to integrate inorganic and organic chemistry throughout both introductory and intermediate chemistry; (2) to fashion a laboratory sequence that promotes student understanding of the qualitative and multidisciplinary aspects of chemistry, including the use of modern instrumentation beginning in the first semester; and (3) to create lecture and laboratory texts for use with such innovations. A unique advantage of this sequence, absent in the traditional, organic first, and two cycle approaches, is the overall matching of topic development to student ability over the two year sequence. This approach builds, from an empirical basis, those unifying concepts of chemistry throughout a two-year sequence. By removing the barriers separating the branches of chemistry at the introductory and intermediate levels, students have a more integrated view of the subject, and have fundamental concepts reinforced with the widest possible variety of chemical examples and explanations.

The success of this innovation is being evaluated by measuring both student satisfaction and student comprehension. Student satisfaction is determined qualitatively by response to questionnaires and quantitatively by the attrition rate after each of the four semesters. Student comprehension is measured via standardized ACS exams.

Texts are being made available for use at one or more alternate test sites, and both the texts and evaluations are being reviewed by an independent advisory committee of experts in chemical education from small, medium, and large colleges and universities. This model of curricular innovation was presented for discussion at the 1995 meeting of MACTLAC. Colleagues are being recruited to critically evaluate the texts as they are produced. Adoption of this innovation at alternate trial sites is being encouraged to help assess its utility, and findings will be published.

Theme-Based Bidisciplinary Chemistry Laboratory Modules

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Chemistry

The fundamental tenet of this project is that student interest in science will be aroused and student understanding of the scientific method will be enhanced by the introduction of multiweek bidisciplinary laboratory modules at the end of each semester in the introductory chemistry sequences—general and organic chemistry. The laboratory modules are organized around themes that have broad-based relevance: water analyses due to environmental concerns; plant assays in response to environmental matters and biochemistry interest; and drug design in recognition of the large pre-medical student population among the students enrolled in the introductory chemistry courses. The laboratory modules are designed to imitate aspects of research by allowing students latitude in formulating specific goals for the project. This is done by incorporating a longitudinal component to the study for the establishment of a qualitative and quantitative database, and by forging research teams both within the individual teaching laboratories and also by bridging student groups across courses in related science disciplines, such as chemistry and biology or geology.

After completing the bidisciplinary laboratory modules, students communicate their scientific results at a poster session. The exchange of ideas that results from the poster session will further encourage student involvement. It is hoped that the bridging concept will find universal adoption at the college and will thus serve as a general pedagogical paradigm for an efficient, logical utilization of the multidisciplinary approach to teaching science.

A group of ten faculty from five science departments constitute an internal advisory committee for program evaluation. After program testing is complete, the advisory group will be expanded to include science faculty from other institutions.

Dissemination of results will occur via presentations at national ACS meeti ngs by publication of laboratory modules

A New Investigative Laboratory for Introductory Organic Chemistry Involving Polymer Synthesis and Characterization

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Chemistry

The project addresses flaws in experiments commonly taken from a laboratory textbook (often called cookbook) which fall short of providing exciting and intellectually stimulating experiences. To remedy this situation, the project is developing a model comprehensive organic laboratory curriculum that gives students the opportunity to be imaginative and creative, leads to better understanding of the concepts that underline scientific research, and is an important connection between theoretical and practical organic chemistry. Individual exploratory research projects are designed for the last quarter of a three-quarter laboratory course that integrates the instructor's research interests with learning experiences for the students. The vehicle is individual organic and polymer syntheses that combine classic organic chemistry and polymer chemistry. The course is structured in a guided discovery model. Each student, in a problem-solving manner, utilizes his or her knowledge and skills learned from the previous two parts of the lab sequence to prepare a monomer via an organic synthesis and a polymer by a polymer synthesis. The research is an open ended laboratory project which includes a microscale monomer synthesis and characterization, scale-up synthesis and characterization, and polymer synthesis. By changing functional groups on the vinyl monomer molecule, the class can explore the reactivity of one "family" of compounds and, subsequently, polymers. This provides the opportunity to make some rough structure-reactivity correlations at the end of the course during group discussion in the class. Pedagogically, this approach makes a point that chemistry is an experimental science in which one can test ideas about both structure and reactivity. The project addresses the improvement of the quality of the undergraduate organic laboratory course model which simulates research activities in the interdisciplinary field of organic chemistry and polymers in three needed areas: the articulation of the instructional model more clearly; the enhancement of the laboratory instruction with the use of computers; and the development of tutorial resources as remedial support for students. Efforts at improving and assessing the value of this curriculum in ways that inform the development of the course and guide research on the learning outcomes will continue. The project also involves the dissemination of the model, highlighting curriculum design and instructional underpinnings to fellow colleagues, as well as to colleagues on the national level, through presentations at local and national conferences and through journal articles.

The Inorganic Illustrator: a 3-D Graphical Supplement for Inorganic and Bioinorganic Chemistry Courses Distributed on CD-ROM

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Chemistry

The visualization of complicated three-dimensional inorganic, bioinorganic, and solid state chemical structures is a particularly difficult problem when the primary means of communication is the two-dimensional world of textbooks, blackboards, and overhead projector screens. Due to the increased performance and availability of personal computers, both instructors and students are beginning to embrace interactive multimedia as a means of communicating chemical information. The goal of this project is to provide on CD-ROM a wide variety of manipulatable molecular models, miniature movies, and dynamic animations that address the topics in inorganic and bioinorganic chemistry that will most benefit from a multimedia format. The free software Chem3D Viewer is being used to present a database of hundreds of accurate crystal structures that will benefit students and teachers at all levels who encounter inorganic structures. Stand-alone tutorials that describe the use of the software and explain difficult structural concepts of inorganic chemistry are being produced. Dissemination of test versions will be via the Internet, followed by the complete version on CD-ROM, and evaluated by polling users at a variety of small and large institutions.