Project Socrates: Improving Physics Education Through Interactive Engagement

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DUE-9253965
FY 1993 $ 104,149
FY 1994 $ 123,665
FY 1995 $ 119,692
Physics

Project Socrates is contributing to a critically needed national improvement in university introductory physics education through research on, and development of, interactive engagement methods for cost-effective mastery learning. In particular, this project is further developing, improving, and promulgating the Socratic Dialogue Inducing (SDI) lab method which has been shown to be effective in promoting student crossover to the Newtonian world. The focus is on mechanics and related areas (fluid statics and dynamics, oscillations and waves). The testing ground is General Physics I, a large-enrollment, non-calculus course for science (but not physics) majors (including prospective high school and middle school teachers). "Real-world" in-class investigation, well-controlled out-of-class research with paid student subjects, and in-depth case studies are being utilized. The goals are to (1) improve and systematize the Socratic-dialogue and SDI lab techniques; (2) collaborate with other instructors to modify the SDI method for various instructional settings; (3) improve and extend the laboratory modules and instructors guides; (4) disseminate the method widely by means of publications, talks, workshops, and distribution of videotapes and lab modules; and (5) continue the construction of computer force-motion-vector animations to assist laboratory and lecture instruction.

Peer Instruction: Stimulating Renewed Interest in Physics and Other Science and Engineering Courses

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DUE-9254027
FY 1993 $ 100,000
FY 1994 $ 100,000
FY 1995 $ 43,500
Physics

This project addresses the problem of widespread student dissatisfaction with traditional introductory science courses. Project work indicates that the primary cause of this problem is that too much emphasis is placed on problem-solving skills, while too little time is spent explaining and discussing fundamental concepts. As a result, students often memorize problem-solving strategies without understanding the concepts that underlie their manipulations. The passive lecture format generally employed in introductory classes further exacerbates the problem. This project addresses these difficulties by adopting a simple and effective instructional technique—ConcepTests coupled with Peer Instruction—that helps revitalize instruction and improve student understanding. The two principal objectives of the technique are (1) to expose students' common misconceptions about fundamental principles via ConcepTests, and (2) to rectify these notions and promote greater understanding of fundamental principles through peer instruction.

The project is implementing this method in an introductory calculus-based physics course and has already collected massive amounts of data on students' attendance and improvement, and on the effectiveness of the technique. Preliminary evaluation of these data has shown that the new lecture format and its emphasis on conceptual understanding and student interaction have led to improved student performance both on conceptual questions and on traditional numerical problems. This initial investigation is continuing; methods and conceptual questions are being adapted and refined based on these preliminary experiences. The project is extending this work to include further detailed data analysis, as well as the compilation of a collection of ConcepTests covering the entire introductory physics sequence. The project is disseminating the initial research results in invited talks at various conferences, and detailed statistical analysis is being carried out and prepared for publication. Although results have only begun to be catalogued, instructors at a variety of institutions have already adopted the method with very positive results. In addition, the method has been implemented with positive results in the introductory physics course for engineering majors at the University of Massachusetts, Lowell by Professor Albert Altman. The success of the method in these various institutional settings indicates that the utility of the technique is not limited to any special audience and does not depend on student background or prior experience.

Project-Centered Physics Curriculum

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DUE-9455656
FY 1995 $ 52,248
Physics

This project addresses the development of five new upper-level courses in a renovated physics curriculum. Since only about 3% of students in introductory physics courses nationwide continue on to upper-level courses, the curriculum must be made more appealing and the aims broader. Traditional curricula have been directed almost exclusively toward the training of undergraduates for graduate school and thence to becoming "physicists." Without sacrificing that goal, the aims of the undergraduate program can be broadened to provide benefits to those who will apply their conceptual understanding and logical problem-solving abilities to a wide variety of future activities. Courses within the model Dickinson College physics major curriculum are to be project-centered, dealing with real-world topics that appeal to students' curiosity. Learning is motivated not by a vague possibility of future usefulness, but by an immediate need for understanding in order to deal with the course projects. This approach is an outgrowth of the Workshop Physics introductory courses developed at Dickinson College, a program that has been used at many other institutions. In a similar way, the new curriculum, the newly developed courses, the project modules, or supporting materials can be useful to other institutions. Projects included in the new courses overlap topics covered in traditional courses, but provide new emphases. For example, experiments with chaos are being incorporated into the dynamics course and magnetic resonance imaging is joining other modern physics topics in medical and radiation physics.

Course Modules in Apparatus Design and Experimental Techniques

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DUE-9552121
FY 1995 $ 94,547
Physics(LLD)

Insufficient attention is given in science curricula to training students, at an early stage, in the practical techniques of laboratory work. When students begin undergraduate research projects, industrial co-ops, and jobs, many are ill-prepared to construct, select, adapt, and use scientific equipment. This project introduces a series of self-contained course modules in practical methods that begin after the first year of college laboratory courses. Six foundation modules form a one year course: (1) materials, mechanisms and machining; (2) basic electronic circuits and measurements; (3) signals and electronics for signal conditioning; (4) computer-assisted experimentation; (5) introduction to metrology and transducers; and (6) optical systems. Upper-division elective modules are: (7) vacuum systems and surface technologies; (8) feedback control; and (9) lasers and optoelectronics. In five weeks, each module covers a small number of the most basic methods and technologies of a topic. There are 90 minutes of discussion, lecture, and demonstration and four hours of lab per week. Students document their practical experience through individual portfolios of their projects. The modular form of this course material makes it readily adaptable to other colleges, where further topics can be developed in the same format. Student lab manuals, exercises, suggested projects, lecture transparencies, demonstrations, software, designs, and parts lists will be available and continuously updated over the Internet.

Physical Science: Reasoning and Conceptual Patterns

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DUE-9455613
FY 1995 $ 69,678
Physics

This project is developing a one semester physical science course for non-science, especially elementary education, majors. This course represents an important element in IPFW's teacher preparation sequence. The course is designed to enable the elementary education majors to implement activity-based curricula following the new guidelines from AAAS and NSTA. The course is activity-based with investigations and exercises designed to elicit students' common sense ideas about the systems and situations, challenge those ideas where they disagree with the scientifically accepted ideas, and help the students construct a new understanding of the concepts, principles, and relationships that apply. A limited set of investigative and reasoning processes, e.g., making observations and inferences, proportional reasoning, and drawing, reading and interpreting graphs, is emphasized and used throughout the course. In order to get the students to engage in the appropriate reasoning and to give them sufficient time to undergo conceptual change and construct a scientifically acceptable understanding, only selected concepts, principles, relationships, and topics are explored. Several concepts and principles, e.g., area, volume, density, and conservation of mass, are examined because of their importance in both chemistry and physics. In addition, two fundamental topics, motion in a straight line and the basics of compound formation, are studied to illustrate some of the contrasts between the two disciplines. The course materials emphasize pattern finding and analysis and are being designed so that the students have to use qualitative means to work the majority of the tasks encountered. During the second year of the project, students will be pre-tested and post-tested using an instrument designed by two independent evaluators. A students' manual and an activities/exercise manual are being developed and will be made available to other instructors on request. Reports on the project will be presented at state and national science teachers meetings.

Implementing Interactive Laboratory-Based Learning Techniques in Second-Semester Introductory Physics

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Research shows that students use formula-centered, problem-solving strategies that differ from those used by experienced scientists, and that the knowledge students gain in introductory physics is a randomly organized set of facts and equations, with little conceptual understanding and many persistent misconceptions. These problems persist even for students who have had physics both in high school and in college. Many approaches have been developed to overcome these problems and have met with reasonable success in small institutions or for particular professors. A challenge remains in transferring these approaches to larger universities. Also, graduate students, the future instructors of science, are generally inadequately trained as educators.

The goal of this project is to overcome these problems through the development of a teaching system that is standardized and made available to larger engineering schools, while also being appropriate for smaller institutions. The teaching method involves leading the students from concrete hands-on examples to conceptual understanding through group discussion. Students are taught how to think about physics problems with concepts related to everyday phenomena familiar to the student. Quantitative experimental results provide verification. Cooperative learning, found to increase participation by women and minorities, is emphasized. Graduate and advanced undergraduate students are brought into the teaching process as apprentices, and guiding materials are being developed to acquaint them with the teaching strategies being used. The project focuses on the calculus-based introductory E&M and optics course taken by over 300 science and engineering students annually.

Over a three-year period, the technique is being refined using student testing and interviews to determine what strategies are most successful. The results are being made available in a format designed to facilitate implementation at a variety of institutions. Test versions of the activities and sample discussions have been available on the World Wide Web since 1995. A standard of evaluation for conceptual understanding of electromagnetism, similar to the Hestenes mechanics evaluation, is being developed and will be made available through an AJP publication.

A New Model for Physics Education in Physics Departments: Improving the Teaching of Physics from Elementary Through Graduate School

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DUE-9354501
FY 1994 $ 764,370
FY 1995 $ 754,830
FY 1996 $ 796,330
Physics

This project is developing a comprehensive, multifaceted program to be conducted by the Physics Education Group in the physics department at the University of Washington. The program consists of a group of interrelated projects that focus on undergraduate course improvement, teacher preparation and enhancement, and university faculty development. The goals for the project are: (1) to expand knowledge of how students learn physics; (2) to increase student learning in the introductory physics course; (3) to prepare K-12 pre-service and in-service teachers to teach science as a process of inquiry; and (4) to improve the teaching effectiveness of present and future college and university faculty. These goals are being met by continuing the investigation of student understanding in physics. Results from this ongoing research guide the development of instructional materials for introductory physics students and for pre-service and in-service teachers. In addition, the project is conducting workshops for undergraduate faculty, inviting faculty interns for short-term visits to observe project activities first-hand, and producing a faculty development handbook to help prepare teaching assistants, postdoctoral research associates, and junior faculty for their role as physics instructors. Their book "Physics by Inquiry" was published in the Fall of 1995.

Interactive, Conceptually Based Multimedia Instruction for Introductory Mechanics on CD-ROM

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DUE-9455585
FY 1995 $ 157,690
Physics

This two year project is developing interactive multimedia tutorials for calculus-based introductory physics. They will be distributed on CD-ROMs that can be used by students at school or elsewhere on equipment that will be available to most students upon completion of the project. Extensive testing at many colleges has shown that students enter physics with many misconceptions about motion and force, and that conventional physics instruction produces little change in these beliefs. Not understanding the most basic concepts, they cope by rote memorization of isolated fragments and algorithms for solving problems. Physics education research indicates that the most effective learning occurs when students are active participants and construct their own conceptual models, in contrast to the passive environment of traditional physics lectures. This project is using new technologies and findings in physics educational research to provide a computer-based learning environment that facilitates students actively constructing the conceptual framework of Newtonian mechanics. They are introduced to basic concepts through short video clips of actual events. This is being done using QuickTime, which only requires the proper software; no additional hardware is needed. Computer animations and graphics help illustrate various interpretations and develop the principles involved. Many of these involve confrontations with common misconceptions. Students interact with simulations and physical representations such as vectors, force diagrams, and graphs. With appropriate feedback and help, they are able to compare predictions made from their conceptual models with those of the Newtonian model and the real world. After learning the concepts, students are led through multiple-representation, problem-solving procedures (e.g., free-body diagrams, graphical analysis, etc.), step-by-step with feedback, and using mathematical models that are appropriate for their background and ability. These modules are being designed so that instructors can add their own examples. The programs will be adaptable to courses of different mathematical levels, ranging from high school to university. The final product will have both Macintosh and Windows versions. Initial programming will be done with HyperCard and Macromind Director. The programming of the final product depends on the most appropriate cross-platform authoring program available at that time. During development, modules are being tested with students at San Jose City College, who are mostly minority. Two university professors and two community college instructors are evaluating the initial overall design and the preliminary version of the complete program. Also, a workshop will be held at San Jose Community College for community college instructors to obtain their evaluations of the preliminary version.

Reform of the "Non-Calculus" Introductory Physics Course from a Constructivist Perspective

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DUE-9354528
FY 1994 $ 114,966
FY 1995 $ 98,796
FY 1996 $ 96,309
Physics

The majority of the problems with introductory science courses, and the non-calculus introductory physics course in particular, stem directly from the way instructors conceptualize the teaching and learning process. This project is constructing and implementing a new introductory physics course that replaces the standard non-calculus course at the University of California, Davis. The model is grounded in a constructivist theory of how learning and conceptual understanding actually develop in an individual student. The course must be taught within the constraints normally found at large universities, and thus serves as a viable model for other institutions. This project intends to transform the traditional non-calculus introductory physics course into a constructivist-based course; produce instructor and teaching assistant training materials in constructivist methodologies; produce a student textbook; and support and guide other institutions desiring to make these changes. The expected outcomes include an increase in students' conceptual understanding and appreciation of physics, an increase in math and critical thinking skills in students, and a pedagogically appropriate model of a science course for pre-service teachers.

Production of Short, Animated Videos for Physics that Illustrate the Application of Physics to Technology

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DUE-9455740
FY 1995 $ 34,215
Physics

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This project helps bridge the gap between physics and technology by bringing physics-based industrial and practical applications to the introductory physics classroom. The teaching of such applications in physics courses is essential in order that students understand the value and use of physics in real life and should also make the physics learning process more enjoyable and easier. Most physics instructors at present do not devote much time to technological applications primarily because of class time considerations.

The project is producing several SVHS videotapes containing short animated sequences to illustrate the applications of physics in modern technology at a level suitable for introductory physics courses. Although the primary audience consists of undergraduate college students, the videotapes are also useful for high school science students. The tapes are being prepared primarily through the use of computer animation and SVHS video recording. Each tape contains 5-10 minute expositions of several devices such as compact disks, photocopiers, telecommunication devices, computer chips, computer displays and keyboards, laser printers, fiber optics, medical devices, etc. These tapes will ultimately be converted into laser disks by a commercial agency.

Extensive field testing of the video segments in classrooms at several universities and high schools will be employed to improve their instructional effectiveness and evaluate their impact. Once the project is completed, the resulting materials will be disseminated commercially to insure maximum availability and reasonable cost.

Activity-Based Physics: Curricula, Computer Tools, and Apparatus for Introductory Physics Courses

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DUE-9455561
FY 1995 $ 725,000
FY 1996 $ 525,000
FY 1997 $ 525,000
Physics

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Three related activity-based introductory physics curricula have been developed with major support from the U.S. Department of Education and the National Science Foundation. These are Workshop Physics, Tools for Scientific Thinking, and RealTime Physics. All three curricula use the findings of physics education research, are activity-based, and have involved the design of computer hardware and software for investigation, data analysis, and dynamic modeling. This three-year collaboration between principal investigators at Dickinson College, University of Maryland, University of Oregon, Tufts University, and Millersville State University is extending, enhancing, evaluating, and disseminating activity-based curricular materials, apparatus, and computer tools for teaching introductory physics based on this previous work. The ultimate goals of this project are to continue full-scale efforts to improve the scientific literacy of introductory physics students through the mastery of physics concepts, investigative skills, and mathematical modeling techniques, and to motivate students to learn more science. Throughout the three-year period, a comprehensive dissemination program will be conducted to reach introductory physics instructors at high school and college levels through workshops, public talks, on-site visits to institutions, and journal publications. These dissemination efforts are being supported by the commercial distribution of products through J.C. Wiley & Sons, PASCO Scientific, Vernier Software, and Physics Academic Software. Particular attention is being given to developing physics activities suitable for courses designed for future technicians at two-year colleges and pre-service teachers. A five-person advisory committee meets once a year to evaluate the project.

An Innovative Introductory Physics Laboratory Course

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This project directly addresses the problems of the negative perception of physics and the general lack of science literacy among the broad student population. The variation in preparation in math and science of entering students, and the underrepresentation of women and minority students in science and engineering are equally critical problems being addressed. This project primarily addresses those pre-college and college students who, by virtue of their background and poor high school training, have had little or no opportunity to experience the excitement and beauty of science as an approach to the world. They do not, in general, consider science or engineering as potential career choices.

The course is designed not only to improve the understanding and appreciation of the laws of physics, but also to provide an experience with the instrumentation and methods of modern science and technology. Modern sensors are used for motion, force, temperature, sound and electromagnetic field measurements. The sensors are interfaced to microcomputers, allowing the students to acquire data and analyze their measurements rapidly in order to explore alternative physical hypotheses. Teaching and learning strategies geared to the needs of this special population are developed. These strategies utilize new experiments which are both non-intimidating and rigorous. They are designed to be both discovery-based and goal-oriented, and to provide an introduction to the excitement and creativity of scientific investigation.

The results of this effort are adapted for and shared with a diverse urban population of high school teachers and their students and two-year college faculty and students. The Rutgers-Newark student body and the geography and demographics of the Newark area, coupled with significant outreach efforts, ensure a large minority student participation in this project.

Evaluation efforts range from analysis by invited experts in the field of science education through comparison testing to student interviews and follow-up on career choices. The New Jersey Institute of Technology, Essex County Community College, and several Newark high schools are collaborating with Rutgers in constructing similar microcomputer-based learning laboratories for their introductory physics courses.

Precision Teaching of an Introductory Physics

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DUE-9455470
FY 1995 $ 242,100
FY 1996 $ 80,700
FY 1997 $ 80,800
Physics

Some 40% of engineering students fail to acquire adequate grades in the required Introductory Electricity and Magnetism Physics course. This leads to a high level of repetition and student attrition from programs. The project seeks to improve performance by emphasizing fluency in basic skills through the techniques of "Precision Teaching". The program presents a large number of relatively simple problems and requires the student to strive for a high rate of correct responses. The rate criterion is believed to be key to success. A pilot program was first presented using pencil and paper; but is now presented by computer terminal with machine scoring, time keeping, and records analysis. The number of inadequate grades has been halved. The pilot program indicates that a level of success is strongly correlated with good intuitive understanding. An interactive computer-based simulation of the more difficult and intangible concepts of the electricity and magnetism course is now under development. Included are electric fields, magnetic fields, and the generalization from distributed to continuous charges and currents. The simulation may be student controlled as a tool for assisting with homework problems and is also being incorporated into the Precision Teaching program for presenting exercises designed to enhance intuition.

The existing Precision Teaching program, with the new simulation component, is being enhanced to better emphasize a ramping of problem complexity and skills sophistication. Mastery is to be used as the criterion of completion of each segment. The new program is being presented to groups of students, and the performance is compared with matched control groups. The general progress to graduation of some 2,000 students per year is to be tracked for three years to study the impact of Precision Teaching, to identify factors related to ultimate success, and to analyze short-term performance on the course at issue.

An advisory committee is being formed to guide the program. The program will be tested at other institutions with large engineering enrollments. A pilot study has already been performed at VPI. Towards the completion of the project, a workshop or conference will be organized on the application of principles of Precision Teaching to university-level technical courses.

Physics Resource Packets as a Pathway to Tomorrow's Education

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DUE-9455442
FY 1995 $ 100,564
FY 1996 $ 102,430
FY 1997 $ 34,323
Physics

Rose-Hulman has developed a pioneering "integrated" freshman year curriculum utilizing symbolic algebra and other powerful software. This curriculum now regularly employs active learning through cooperative group work. Little has been done, however, to carry such innovations into the sophomore and succeeding years. Technology is advancing ever more rapidly making it imperative that education be abreast of coming changes. Instructors are slow to change their teaching to include new techniques, due both to inertia and lack of time. The goals of this project are to: (1) reinforce and build on major freshman-year innovations, to maintain and build student confidence in using skills and technology with challenging problems; (2) increase student confidence in the power of technology to generate graphical representations, to manipulate complex expressions, and to re-analyze a situation with new parameters; (3) build student and faculty comfort with cooperative group work. Students need to realize that all major problems facing scientists and engineers today require team efforts; (4) provide faculty with resources to accomplish goals 1-3; (5) disseminate the resources developed in this project to a variety of educational settings; and (6) use materials generated by the Consortium for Upper-Level Physics Software (CUPS) project to further enhance the educational impact.

The specific objectives of the project are to: (1) provide "resource packets" for selected introductory and advanced Rose-Hulman physics courses. Each packet will contain class-tested strategies and examples. This will enable faculty to confidently assign and use resources which meet the goals of this project; and (2) make assignments each quarter in every section of selected physics courses: (a) four or more activities using symbolic algebra tools; (b) four or more graphical output activities; (c) four or more assignments adding simple effects and varying parameters; and (d) at least once-weekly classroom cooperative group activity.

Packet development is being done by a team of faculty from the NSF-sponsored "Foundation Coalition" (Rose-Hulman, Arizona State University, Mesa Community College, Texas Women's University, University of Alabama, and Texas A&M University). A two-day cooperative learning workshop initiated the project. In Phase I (1995), packets were created for six introductory/large enrollment courses. In Phase II (1996), packets were created for five advanced physics courses. Two students were used each summer to generate full *Maple* and *Mathematica* problem solutions. Phase III (1997), involves revision and evaluation. Evaluation will be made by both pre- and post-measurement. It will be publicized via e-mail (phys-L, listserve), and talks presented at summer AAPT meetings. A survey will be developed to track usage and satisfaction with packets.

Astronomy and Writing: An Innovative Approach to Science Instruction

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DUE-9253979
FY 1993 $ 34,000
FY 1994 $ 94,519
FY 1995 $ 47,884
Astronomy

This project helps incoming students develop critical thinking skills and a better understanding of basic scientific principles by constructing an astronomy workbook that utilizes both math and writing. At New Mexico State University, a large portion of the student body is Hispanic, so particular care is being given to constructing exercises appropriate to this group. The workbook utilizes the techniques of "Writing-Across-the-Curriculum" (WAC). Numerous investigations have found that a strong relation exists between writing and learning. Writing has also been shown to be an effective tool in physics and math instruction. The project is exploiting the values of writing as a learning tool in astronomy. The incorporation of WAC techniques into a beginning astronomy class, at this level, is a unique experiment. The intent is that the project will serve as a prototype for future efforts in the physical sciences at New Mexico State University and that the material developed will be transportable to other institutions.

Active Learning Environment for Large Non-Science Majors Astronomy Classes

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DUE-9354525
FY 1994 $ 107,437
FY 1995 $ 87,287
FY 1996 $ 78,688
Astronomy

Almost all universities teach large introductory astronomy classes for non-science majors. These classes are typically among the larger and more popular science classes aimed at non-science majors, and often constitute the last formal science education students will receive. Unfortunately, many of these classes are organized around lectures that demand little or no participation from the students, creating an environment in which the students resort to an uncritical memorization of facts. This project is developing an astronomy class aimed at non-science majors that actively engages students in critical thinking. Modern and relatively inexpensive CCD technology is being used at many universities to teach astronomy observation laboratories to small numbers of astronomy students. This project incorporates CCD technology into laboratories designed for large classes of non-science majors as a method of increasing student participation. It also takes advantage of the numerous computer classrooms available at most universities and expands laboratory analysis into a separate computer homework component. This component enhances the lecture material, increases active learning, and breaks down the barrier between lecture and laboratory. The project pays particular attention to the practical difficulties of achieving these goals in classes that may well enroll 200 students, most of whom are not exceptionally computer literate, and also focuses on the long-term maintenance of such an environment without burdensome and unrealistic demands on faculty time and other teaching resources.

Creating Effective Meteorology Laboratory Modules to Improve Curriculum and Enhance Student Transition into Upper-Division Coursework

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DUE-9551536
FY 1995 $ 305,000
Astronomy(LLD)

The operational and research activities within the field of meteorology are undergoing unprecedented and rapid change. An effective meteorological laboratory curriculum must reflect the latest innovations and theoretical applications of the users of the science. This project is developing a lower-division undergraduate laboratory curriculum that prepares freshmen and sophomores for upper-level study, provides these students adequate time to begin learning their chosen field of study, and supplements the existing curriculum with a balanced and necessary foundation in understanding the tools used for meteorological study. The specific objectives of the project are to: (1) design lower-division coursework in meteorology; (2) create a laboratory manual consisting of computer programs and forecasting techniques to be used in lower-division courses. These laboratories also are designed for maximum flexibility and expanded use in upper-division courses. (3) provide students with skills for an easier transition from sophomore to junior year; (4) encourage other community colleges to develop programs in meteorology; (5) encourage students who are not adept at mathematics to become interested in weather; and (6) motivate students to take higher level mathematics and physics. The project is producing approximately 20 new computer-based laboratory curriculum materials. The modules provide the foundation for the development of courses in weather analysis and forecasting and create new computer-based laboratory opportunities for existing courses in atmospheric science. Self-paced meteorology modules encompassing new technologies with standard universal concepts allow for individualized instruction of meteorology fundamentals. The modules contain lessons in understanding numerical models, forecasting techniques, and data acquisition and manipulation, and are portable to different types of forecasting laboratory environments. The modules give students an opportunity to begin to understand the broad implication of meteorology by piecing together the atmosphere's subtle nuances, and may encourage students to expand scientific literacy by taking mathematics courses that they otherwise would not have considered. The backgrounds of community college students who will benefit from the project include meteorology majors, educators, aviators, and people with an avid interest in meteorology.

Imaging the Universe: A New Curriculum for Undergraduate Astronomy Laboratories

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DUE-9455621
FY 1995 $ 81,660
Astronomy

The project extends and enhances the development of an innovative undergraduate astronomy curriculum based on CCD cameras and robotic telescopes. The emphasis of the new curriculum is hands-on planning and analysis of the student's own images rather than traditional methods using observations from professional astronomers. The primary audience is the non-science major in large introductory courses. The project has three components. The first is revisions and additions to the new laboratory curriculum already written. Fourteen observing laboratories as well as fifteen computer-based tutorial exercises have been developed during the current grant period. Based on comments from teaching assistants and students who have used the draft version of the curriculum, existing labs are being revised and about fifteen labs are being added. The revisions attempt to make the hands-on approach more direct, make the mathematical level more nearly uniform, and better emphasize the imaginative and creative skills of the students. The new observing labs cover astronomical topics not yet addressed in the current manual, including orbits of minor solar system objects, properties of variable stars, variability in active galaxies, and spectral line observation of nebulae and bright stars. New computer-based laboratories include extensive use of the astronomy databases and images available over the Internet. The second component is the development of a software system to schedule and control an automated telescope system using commercially available hardware. The system will be completely self-contained and controllable from any site on the Internet. A prototype system for a custom mount and dome using a low cost PC has already been developed. The system will allow interested colleges and universities to set up a complete CCD-based laboratory for large introductory classes with minimal effort and expense. It can also be used to operate remote dark-site telescopes which could be shared among several schools. The third component is the development of an HTML Internet site at the University of Iowa for dissemination of on-line information related to the use of CCD cameras and robotic telescopes in the teaching of astronomy.

TTECCS: Transforming Technical Education with a Classroom Communication System

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DUE-9453881
FY 1994 $ 302,000
FY 1995 $ 402,860
Astronomy

A classroom communication system is being developed to promote a more dynamic and constructivist classroom environment. Students engage in cooperative learning activities and communicate their understanding to the instructor, thereby permitting the instructor to respond to specific instructional needs. This project is a collaborative effort among science and mathematics instructors at the University of Massachusetts and Amherst Regional High School, educational researchers and curriculum developers at the University of Massachusetts Scientific Reasoning Research Institute, and educational technologists at Better Education, Inc. The project focuses primarily on the subject matter appropriate for a one-year astronomy course at the high school or college level. The complete system is being developed, consisting of hardware, documented software, and curriculum materials. Exemplar materials also are being developed in mathematics and chemistry. A primary aspect of the project is evaluation of the comparative effectiveness of the classroom communication system as an instructional approach.

A Hypertext-Based Study Guide for Introductory Astronomy: Defusing Misconceptions

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DUE-9455529
FY 1995 $ 27,337
Astronomy

The project is developing a database containing 100 highly-linked hypertext questi ons that provide a computer driven interactive study guide for introductory astronomy for non-majors. The goal is to complement traditional text and lecture materials with a new teaching tool designed to improve logical thinking by allowing students to explore and correct natural misconceptions. The hyperlinked environment enables: (1) presentation of multiple levels of information and reasoning; (2) the possibility for deeper exploration by motivated students; and (3) rapid feedback for the instructor and for the students. The 100 questions are selected to span the range of material commonly covered in introductory astronomy. This teaching tool can provide students with a visually attractive, intellectually stimulating alternative path for learning and honing their logical skills. The study guide is being made accessible via the World Wide Web. A controlled test of this instructional tool in an introductory astronomy course is being conducted. At the same time, it is being made available at all interested sites. The level of presentation in the study guide also makes it accessible to advanced high school science students.

Project CLEA: Contemporary Laboratory Experiences in Astronomy

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DUE-9354514
FY 1994 $ 197,800
FY 1995 $ 177,120
Astronomy

Astronomy is one of the most popular courses in the college curriculum for non-science majors and is for many students the first and only college experience in science. But laboratories in introductory astronomy are not conducive to hands-on experiments because of the faintness of astronomical objects, the long time-scale of many of the phenomena, and the fickleness of weather. Most current astronomy exercises rely on analysis of photographs or canned, predigested data, and give little feeling for the power and process of astronomical investigation. Existing exercises also make extensive use of photographs and other techniques that are out of date in the era of digital data acquisition and computer processing.

Project CLEA is developing computer exercises that provide realistic experiences for introductory laboratories based around simulations, digital images, and observations with CCD cameras on small telescopes. Six modules have been developed under previous NSF support, and six to eight are being developed under the current grant. Each module consists of software, illustrated student guides, teacher manuals, and technical documentation. Modules have been introduced into classes at Gettysburg College and distributed electronically to more than 600 individuals and classes worldwide, via ftp, dial-in bulletin board, and mail. The software is evaluated through questionnaires (both for students and instructors), and the project also is conducting in-class testing at Gettysburg College and several other schools. A consultant is assisting in the development of evaluation routines that can be incorporated directly into the programs.

Currently, the most sophisticated modules run on PC-compatible computers under Windows. Under this grant the project converts existing and future software to color Macintosh versions. The new exercises improve students' understanding of astronomy and provide the means and impetus for revitalizing introductory astronomy laboratories nationwide.

An Interactive Introductory Astronomy Course

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DUE-9455293
FY 1995 $ 158,260
Astronomy

An introductory astronomy course is being developed whose primary goals are to: (1) develop quantitative reasoning skills and independence in problem solving; (2) expose students to the scientific use of computers; (3) inculcate an understanding of the power and limitations of experimental data; (4) develop critical thinking through scientific writing; and (5) build on the appeal of astronomy to attract and retain more science majors. The approach emphasizes hands-on problem-solving experience gained by working on projects built around a few themes, rather than the more passive learning inherent in delivery of a comprehensive body of material by a single professor in a traditional lecture setting. Students will be active participants in the classroom both collectively, through critical discussions of project goals, experimental techniques and analysis, and individually, through use of interactive software packages. The project makes extensive use of the hypermedia environment in developing software modules for the course, and eventually these modules will be available to colleagues at other institutions via the Internet. The course materials are being developed by a team of senior faculty and graduate students. The team approach benefits not only the undergraduates who are enrolled in the class, but also provides the graduate students with a mentored experience in designing courses and curricular materials, and thus a valuable introduction to teaching.

Planetary Exploration in the Classroom

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DUE-9455329
FY 1995 $ 109,270
Astronomy

Planetary exploration captures the imagination and inter est of students having both science and non-science backgrounds and aspirations. Current textbooks that simply present a few pictures from planetary missions fail to capitalize on the potential for utilizing the excitement of planetary exploration as a theme for learning about physical processes and the methods of science. This project is developing a curriculum that builds upon the appeal of space exploration to promote interest in science and to teach modern methods of scientific investigation and discovery. It uses a hands-on approach in exploring processes which shape planetary worlds using actual spacecraft images and existing Macintosh computers. Through a set of exercises, students learn that scientific images are no longer pictures in books. Instead, modern scientific images are digital objects that can be manipulated and examined in quantitative detail. Spacecraft images are used to motivate scientific inquiry but the curriculum also emphasizes that digital imaging is becoming inherent to areas beyond science. The new curriculum involving digital imaging is being incorporated into introductory-level classes which attract a broad cross section of science and non-science students. These students should carry their scientific and digital imaging experience with them as new tools in their pursuit of majors and careers in all areas of science, engineering, medicine, humanities, and education. Because the curriculum is at the introductory science level and uses both images and software available in the public domain (for both Macintosh and PCs), these exercises can be available for wide use in other colleges, universities, and high schools.