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From a careful description of the rationale and implementation of a large-enrollment, science-based, introductory class, faculty can use an interdisciplinary course model to explore specific and innovative mentoring opportunities. This model describes a hierarchical mentoring system with key roles for faculty team members, graduate students affiliated with the class, and undergraduates.

Mentoring Interdisciplinary Undergraduate Courses

Timothy L. Killeen

In this chapter, I discuss the special needs and opportunities for effective faculty and graduate-student mentoring of undergraduates in an interdisciplinary model. These undergraduates are enrolled in large science-based, interdisciplinary, introductory (SBII) courses. I derived the commentary from five years of experience as the course director for the two-semester sequence—*Introduction to Global Change, Part I: Physical Impacts* and *Part II: Human Impacts*—at the University of Michigan. Although this model is specific with regard to topic and campus location, any interdisciplinary faculty team can apply the lessons learned and possible implementation strategies.

New experiments with introductory science curricula, such as the University of Michigan's Global Change courses, are being conducted for two principal reasons. First, these courses are influential in determining students' career and academic choices, often providing the final opportunity for certain students to gain a basic appreciation for science and the scientific method as part of their general education. Second, past assessments in many disciplines have shown that students can sometimes be permanently alienated from science by traditional courses that emphasize rote learning. In response to these concerns, extensive efforts were made during the past decade to reform introductory curricula in mathematics (Artique, 1999), chemistry (Lloyd, 1994), physics (*Physics Education Research,* 1999), biology (Coalition for Education in the Life Sciences, 1999), and other disciplines, as well as to develop new interdisciplinary courses, designed to be broadly accessible to and appealing for first-year students. The mentoring in these classes is a key source of motivation for students to continue to study science.

As a unique mentoring option, interdisciplinary courses for introductory science-based curricula are no longer as novel a concept as they were in the early 1990s, but the effective implementation of such SBII courses, and their evaluation in terms of student learning, represents a significant challenge and opportunity for undergraduate educational reform. The large enrollments in these courses mean that direct, one-on-one, faculty-student mentoring will be constrained by the practical considerations of limited faculty time. Therefore, other mentoring techniques (the hierarchical model) must be used to help all students reach enhanced levels of more active and collaborative learning. In some sense, the initial development and continuous improvement of these important large-enrollment courses demand the "wholesaling" of techniques that have proved successful in smaller, more intimate settings, where direct faculty mentoring is possible.

In this chapter, I describe how the University of Michigan Global Change introductory course sequence has been adjusted to improve student learning and to raise student levels of interest in science through use of mentoring by faculty and graduate student instructors (GSIs), the implementation of active learning strategies, the deployment of new instructional technologies, and the use of feedback derived from extensive formative and summative assessments.

Background and Motivation

The need for effective science, mathematics, engineering and technology (SME&T) teaching at the introductory undergraduate level is one of great import and scale. Consider that, in the U.S. postsecondary educational system alone, there are roughly 14 million students enrolled in 3,600 institutions, and these students earn 1.9 million degrees per year (about 1.4 million are granted in nonscience and engineering areas). These students (both science and nonscience majors) are the teachers, legislators, industrial decision-makers and researchers of tomorrow. All of these students will need a working background and knowledge of science to confront the complex challenges of an increasingly technological society in a world of limited natural resources (Clinton and Gore, 1994).

It is clear that we cannot afford a postsecondary educational system that "turns off" students from even a rudimentary appreciation for scientific thought and quantitative analysis. Yet, there are alarming indications that show that's exactly what is happening. At the K–12 levels, for example, the findings of the Third International Mathematics and Science Study (TIMSS) provide cause for concern. These findings were reviewed by the U.S. National Science Board (NSB) which subsequently issued the call to arms, "Failing Our Children, Implications of the Third International Science and Mathematics Study"(National Science Board, 1998). The TIMSS report showed that only one quarter of U.S. high school students enroll in physics and only one half in chemistry. In a later and more complete analysis of the TIMSS data, the NSB developed recommendations for needed reforms in instructional materials, teacher preparation, college admission strategies, and evaluation and assessment research (National Science Foundation, 1999).

At the undergraduate level, there are similar indicators of a systemic failure to capture the interest of students who are not (at least initially) inherently motivated to study SME&T topics. A study in 1995 indicated that fewer than 20 percent of students take an SME&T course after their freshman and sophomore year. College attrition rates are very high. Of the 2.4 million students entering four-year colleges in 1993, 1.1 million left without a degree. The graduation statistics are lower for specific underrepresented groups, such as Hispanics, who graduate at a rate of 35 percent, and African Americans, who graduate at a rate of 45 percent (Tinto, 1993). Regarding science education, disturbing facts are often heard. Some surveys of Americans indicate, for example, that less than 50 percent of adults know that the Earth orbits the Sun once per year and that only one person in fifty was able to describe the scientific process, accurately, as one that is based on a process of observation and hypothesis testing. The central concern here, of course, is that fewer and fewer citizens are comfortable with the concepts of science and technology at a time of greatly expanded societal reliance on such tools. This is a concern that must be shared among all faculty and administrators in higher education.

The recent report of the National Science Foundation entitled, "Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering and Technology"(National Science Foundation, 1996), and Volume II of that document, published in 1998 (National Science Foundation, 1998) point to specific reforms to address these problems. The central recommendation from these reports is to better integrate research and education and provide more active learning opportunities for all students, regardless of background. In other words, students will become motivated and will learn if the materials are presented in a manner that is interesting and *engaging*. There is general consensus and much evidence that effective mentoring techniques are central to such reform. The mentoring is an essential element of the motivation to continue to study science.

The Undergraduate Research Opportunities Program (UROP) Model

The past decade has, in fact, seen numerous successful reforms, designed to link research and education and enhance faculty-student mentoring at undergraduate institutions. Many universities, for example, have adopted the Undergraduate Research Opportunities Program (or UROP) model. UROP matches undergraduate students with individual faculty members, thereby enabling the students to conduct authentic research and scholarly activity in research labs, libraries, and studios. Results from published evaluations of such programs indicate that they lead to improved student outcomes in the critical metrics of both retention and scholastic achievement. The University of Michigan's UROP, which involves more than nine hundred students annually, for example, has been carefully evaluated with a process involving equivalently qualified control groups. The University of Michigan UROP includes a peer advising group component, as well as the core faculty-student research partnership, such that mentoring occurs at both the peer and faculty levels. An evaluation of the University of Michigan UROP (Nagda, Gregerman, Jonides, von Hippel, and Lerner, 1998) has demonstrated that retention rates rise for most categories of students. For example, underrepresented minority participants in UROP, studied from 1989 to 1994 had an attrition rate of 11.4 percent compared to 23.5 percent for nonparticipants. While still in their infancy, such systematic evaluations generally support the extensive positive anecdotal evidence familiar to most individuals involved in such one-on-one mentoring programs.

Table 10.1 summarizes some of the UROP intervention strategies and the student outcomes tied to these strategies, as determined from the UROP assessment work. It is generally accepted that the effectiveness of UROP is attributable, at least in part, to the intensive mentoring received by program participants at different levels—by faculty, by other members of faculty-led teams (for example, graduate students and postdocs), and by peer groups. The feeling of being welcomed on a large campus, of making useful contributions to research, and of the enhanced collegiality associated with a more intimate relationship with faculty are all key components.

Table 10.1. Elements of Mentoring Success Exemplified Within UROP Programs

Element	*Student Outcome Facilitated*
One-on-one faculty mentoring	Academic competency Critical thinking Academic integration Enhanced retention
Feeling of being welcomed on campus	Participation in learning communities
Peer group advising	Connections between classroom theories and concepts
Research participation	Computer literacy Teamwork Substantive reading Hands-on activities Logistics and problem-solving skills
Learning skills and career development workshops	Computer database management, library research in the information age, exploring the Internet, abstract writing, and time management
Annual Symposia	Oral and poster presentation skills

There remains a challenge of scale, however, and it is one exemplified by the University of Michigan situation. The 900 UROP students are a relatively small fraction of the 23,500 undergraduates enrolled in classes. Consider first an essential question. How can the positive attributes of UROP-like programs be distilled and incorporated "wholesale" into the standard curriculum? In this context, the introductory, interdisciplinary course is a relatively new curriculum tool that has significant potential. Consider also a more-focused question. What elements of successful student outcomes as seen within the UROP model (Table 10.1) can be attained within the constraints of a more traditional classroom experience?

Variety of Mentoring Strategies Available in SBII Courses

The SBII model provides mentoring options for all the faculty who are involved plus roles for graduate student instructors and undergraduates themselves.

Team Teaching. SBII courses can be developed and taught in various different ways. Typically, such courses are developed around a clear focus provided by emphasis on a theme or a collection of themes. Thus, for example, SBII courses in earth-system science are often taught with a *place-based* theme or a focus on a *resource* in question (for example, drinkable water). The courses are sometimes taught by individual professors who attempt to become sufficiently familiar with materials outside of their research area to give an interdisciplinary overview. Alternatively, SBII courses can be team taught, using expert instructors from the various intersecting disciplines, with all the challenges that this implies for overall course coherence and coordination. The latter approach is quite hard to accomplish successfully, even though the commitments on the part of individual instructional team members are smaller in magnitude than would be the burden on a single instructor. These difficulties arise because of the cultural and jargon differences between university departments, teaching styles, and even the manner in which scientific content is described across the disciplines.

The team-taught SBII course, however, has several significant potential advantages for active student learning and for an expansive mentoring approach. These advantages include (1) the exposure to diverse points of view and faculty from different parts of the university at an early date in students' undergraduate careers, (2) the possibility of institutional commitments of resources, in addition to those from the individual departments, and (3) the general enrichment of the curricular content due to access to the continually refreshed expertise of the instructors teaching in their research fields of interest.

This curricular enrichment often involves the use of instructional technologies, combining materials from the different disciplines by using multimedia and Web-based means. Additional student interest can be gained through the development of modular "case studies" of interesting topics, derived from the particular disciplinary backgrounds of instructional team members. These case studies can often be made relevant to the life interests of students, thereby engaging further involvement and appreciation for the applicability of the scientific underpinnings to matters of interest to the students.

Hierarchical Mentoring. Mentoring within an SBII course is often considered primarily in the context of graduate student instructors (GSIs), who are responsible for grading and managing lab offerings, and who often also provide student office hours for consultation. It is important to expand this thinking in the light of the powerful example of successful mentoring in UROP and other programs (Table 10.1).

The GSI is, of course, a keystone player in the student-faculty-pyramid resource and careful course design is needed to optimize the impact of graduate student participation. For example, we have found that lab sections of greater than twenty students are much less successful in terms of student mentoring than are smaller groups. This upper limit (maximum twenty students per lab section) essentially sets the institutional price for an SBII course. GSI training should include attention to the importance of mentoring in all interactions with the students. Such training should occur very early in a given term or semester to set the tone for the ensuing work. Thus, for example, the GSI-led lab section could and should be seen primarily as a mentoring experience, with graduate students fostering the development of learning communities, team building, computer, and communication skills. The term paper or team project can also be viewed explicitly as a mentoring experience, with the GSI soliciting student ideas initially, then having the students formulate the research plan more concretely in written form, and finally aiding the development and "publication" of the research project.

Teaching faculty can also participate in the mentoring of students in large-enrollment SBII classes, though this often takes the form of e-mail advice and exchanges with larger collectives of students. In a faculty team setting, the effort can be distributed by having standing agreements that designate which faculty member handles what class of query or comment. We have found that e-mail listservs are excellent resources for faculty mentoring of students. Also, faculty interactions during two-to-three-hour review sessions prior to each midterm and final exam, "movie nights," and other such activities all provide opportunities for faculty to engage with the large student group more actively outside of the classroom. Within the classroom, time can be allotted for open discussion and for questions with all faculty participants and the whole class.

Finally, undergraduate students themselves can contribute to the mentoring environment within the SBII course. We have used undergraduates as Web developers, as course coordinators, and as content developers for the University of Michigan Global Change courses (implementation through the UROP) and this has proved remarkably successful. In fact, undergraduate students who have taken the Global Change course sequence are very well positioned to advise the new group of students, providing an element of peer counseling. Also, honors student groups can improve the lab and lecture content through accelerated projects that go beyond the standard curriculum.

In summary, the design of the SBII course, GSI training and course staffing, and the course content (cadence and exposition) can all be optimized around the goal of the mentoring of the undergraduate student. In this way, the large-enrollment SBII course can mimic many of the attributes of the more intimate one-on-one mentoring afforded by UROP. Required alterations in the SBII design to make this happen, however, are not always self-evident, and a well-crafted evaluation program (including formative elements) can serve to identify and prioritize the needed modifications. These techniques are very successful in improving student attitudes towards the introductory science-based course experience.

Active Learning Strategies. The SBII course lends itself well to the development of active learning strategies. Courses with a major lab component can offer specific research activities that include the elements of teaming, oral and written presentations, hands-on research, and so on. Student groups can be formed to develop end-of-term Web posters on a topic of their choice, bringing in the important teamwork and team-building skills. The use of the Internet can facilitate student access to items such as self-tests, evaluation instruments, student portfolios, and links to other resources that provide active learning experiences. Group e-mail listservs can be used to provide electronic communication pathways for subsets of students, for student-graduate interactions within a lab section, and for the whole class, including the instructional faculty.

Institutional Reforms. Experience with the University of Michigan Global Change course has shown how valuable such a strategy can be. The optimization of an SBII course to serve the mentoring function described above requires an institutional-level commitment. It must be recognized that such courses are more (not less) expensive than other types of introductory science courses. The faculty time commitment needed to prepare and particularly to coordinate lectures is considerable, the lab sections have to be kept small to foster communication, sufficient numbers of graduate students need to be hired and trained effectively, site licenses may be needed, a special classroom may be required, and additional personnel needed. The University of Michigan Global Change course, for example, requires a "course coordinator" position, outside of the regular instructional team, to facilitate and enable the details of managing a complex educational experience (dealing with, for example, site licenses, meeting rooms, scheduling issues, curriculum committees, and so on). Also, extensive use of the Internet requires specialized expertise and a dedication to continual maintenance of the system (inactive and poorly maintained Web sites can discourage active student learning). The University of Michigan Global Change course team includes a graduate student dedicated to maintain the Internet site.

Another type of commitment from the institution might be in the form of an evaluation and assessment program. SBII courses are, by their very nature, somewhat experimental. They need to be tuned for performance, to reduce redundancy and ensure that the lab sections and lectures are properly synchronized. The best way to ensure that the curriculum meets its potential is to conduct a formative and summative evaluation program. Experience with the University of Michigan Global Change course has shown how valuable such a strategy can be.

All these components add up to a significant level of support needed from the institution. The "hero" model of a successful course, where an extraordinarily committed individual manages to inspire the students and create a masterful curriculum, is less likely to work within the constraints of an SBII course, where a larger team is necessarily involved. Successful examples of such SBII courses need to be institutionalized to ensure that the perhaps considerable institutional investment is not lost over the long term, when key instructors go on sabbatical, for example. Convincing the institution of the need to provide and sustain the commitment of such resources over time is a significant challenge that must be met if such courses are to succeed.

The University of Michigan Global Change Course Sequence Model

Experience with the Global Change course sequence has demonstrated the usefulness of multifaceted mentoring approaches within the context of a standard-format class. The Global Change course sequence has been designed specifically for nonscience majors from any school or college within the university and from any academic background. The course development has been funded by the National Science Foundation through its program the Institution-Wide Reform of Undergraduate Education (DUE–9652117). As such, the curriculum has been used as a test for reform approaches designed to provide more active, inquiry-based learning in SME&T topics for all undergraduates enrolled at a large public university.

An interdisciplinary faculty group from six departments and schools initiated the Global Change sequence in 1990. Professors involved in team teaching the course come from the Department of Atmospheric, Oceanic and Space Sciences in the College of Engineering, the Departments of Biology, Geological Sciences, and Sociology in the College of Literature, Science, and the Arts, and from the School of Natural Resources and the Environment. An independent evaluation team from the School of Education has been part of the team since the inception. After two years of planning and after arranging the necessary cross listing, the curriculum was first offered in 1992. The sequence currently involves two core courses at the 100 level, the first (offered in the fall term) deals with the physical impacts of global change and the second (offered in the winter term) deals with the human impacts. As with other courses of its type, the Global Change sequence uses Web-based tools extensively. All the lecture notes are posted on the Web (http://www.sprl.umich.edu/GCL) with each professor adopting a common format for each module, comprising objectives, readings, hyperlinks, updated text with copyright-cleared graphics and animations, a summary, and a student self-test. The course is therefore enriched by an electronic text, which is under continual revision to reflect new findings by experts in the various disciplines.

In addition, the undergraduate students develop a sense of "ownership" for the course texts by suggesting links, developing their own home pages, and team projects on the Web. Similarly, each lab is Web-based. The first semester exposes students to a dynamical modeling package, Stella™, and the second semester uses a Geographic Information System (GIS) package, ArcView™. The dynamical modeling package allows students to work directly with nonlinear complex systems to develop an improved understanding of change and causality. For example, students develop models of the earth's energy balance that are used to study global warming scenarios based on a description of atmospheric processes and projections of the buildup of carbon dioxide in the earth's atmosphere due to fossil-fuel use. Similarly, the GIS package enables students to study aspects of the global and regional utilization of resources, using a simplified version of the same tool used by governmental and nongovernmental decision-makers, such as the World Bank. These two software packages enable students to work directly with key problems in global change and examine remediation and mitigation strategies in a quantitative, hands-on manner.

A "Web poster" project is required of all students and they form teams (two to four students each) early in the term and work subsequently to develop and present their projects. Students are asked to formulate their project plan in writing, and this proposal is reviewed by the GSIs. Past experience has shown how these efforts can serve to create nested learning communities within the student body, while also providing for extensive GSI-led mentoring opportunities.

The overall goal of the Global Change curriculum project was to develop an introductory science-based course sequence that would provide *all* students, regardless of background or mathematical proclivities, an opportunity to gain the benefits and insights from a modern and continually updated scientific description of the changing global environment and the human relationship with that environment. It was felt that the issues to be discussed in such a course could be made directly relevant to the future lives of students, thereby making the content of significant appeal and interest. A key objective from the beginning was to make the course truly interdisciplinary, through a team-teaching approach, involving expert faculty from the key intersecting disciplines. The goal was to make the course both rigorous and quantitative in terms of its scientific content and still be engaging and appealing to non-science majors, through the extensive use of multimedia techniques and new instructional technologies. Both terms carry four credit hours and involve three hours of lecture and a weekly two-hour lab, together with a team project activity. The enrollment has steadily grown to the current maximum of two hundred students (primarily first year nonscience majors).

In order to assess the effectiveness of the curriculum development effort, a comprehensive evaluation plan was developed and implemented by an independent team of educational researchers not directly affiliated with the instructional team. The evaluation plan was designed to use both formative and summative perspectives to guide the development of the curriculum over both the short term (lecture to lecture and lab to lab) and the long term (year to year). One of the principles of the evaluation plan was to adopt a comprehensive and intensive approach, integral to the overall program, avoiding last-minute add-ons. Formal course objectives were articulated (Exhibit 10.1). Weekly meetings of the instructional team and the evaluation team, for example, were instituted in 1995 and have continued through to the present. A particularly valuable component of the evaluation approach has been the "minute paper" that each student is required to fill in after every laboratory exercise. Minute papers document the students' immediate response to the particular curricular element and, when reviewed over time from a statistical point of view, provide very clear guidance as to the optimal content and the cadence for the introduction of lab materials.

The Global Change team at any time typically includes four to six primary teaching faculty, five to six graduate student instructors (GSIs) drawn from various schools and colleges, a three-person evaluation team (one faculty

Exhibit 10.1. Objectives of the University of Michigan Global Change Curriculum

1. To improve students' understanding of the interdisciplinary scientific underpinnings involved in the study of Global Change.
2. To study the evolution of the physical world to enable students to better appreciate the temporal and spatial scales of changes that have occurred in the past as well as those that might occur in the future.
3. To understand why Global Change studies require a system perspective in which many interacting components must be described.
4. To become better equipped to contribute to the important debates concerning global resource management, environment, environmental impact, and societal adaptation strategies.
5. To learn to use the vast resources of the Internet to find and use environmental information.
6. To learn to develop simple dynamical models of Earth system processes and to understand the importance of computer modeling of Earth's complex physical systems as well as the limitations of their use.
7. To learn about the inadequacies in the data and knowledge regarding Global Change and to learn about emerging strategies to improve the state of our knowledge.

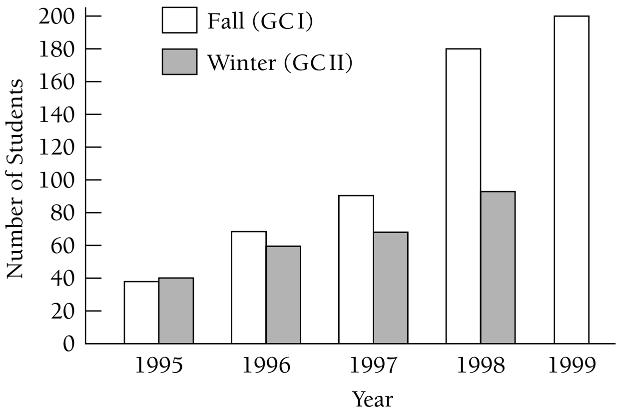
member and two graduate students), a student "Web-master," and several undergraduate students enrolled in the University of Michigan UROP, working on specific aspects under the supervision of one or another of the teaching faculty. This relatively large interdisciplinary team is exposed on a weekly basis to the results of the evaluation program, thus providing motivation and information to track the effectiveness of all course components. The weekly meetings provide a forum for GSI training and an opportunity for the faculty to refine the course content in the light of findings from the evaluation team. This team approach provides a hierarchical mentoring system to support the enrolled undergraduates, and much of the information gleaned from the evaluation effort has led to improvements in this mentoring process.

The course sequence was designed from the outset (1) to serve all students, regardless of level of scientific background and (2) as a coherent interdisciplinary product, using the diverse strengths of faculty at a large research university. Both of these goals were easy to articulate but quite difficult to achieve in practice.

Accessible Science for All Students. Inspired, in part, by the "Shaping the Future" document and by the goals of the NSF Institution-Wide Reform program, the introductory sequence was designed to serve all students at the University of Michigan. Figure 10.1 shows the rise in enrollment from the time of the first Web-based offering. Because the course sequence was, by its nature, interdisciplinary, it did not belong to any one school or college and this meant that academic advisers were not as likely to recommend the course to incoming first-year students. Student awareness of the course sequence was, therefore, largely developed through word of mouth and this led to a relatively slow increase in enrollment. The slow increase threatened the course sequence, and patience was needed. Currently, the course is oversubscribed and initial discussions are under way about opening a second lecture section. The course sequence also forms the basis for an interdisciplinary minor in global change, approved by the University Curriculum Committee in late 1999.

Interdisciplinarity. Although the course sequence was initially designed to be team taught, several years elapsed before the course material was actually presented in a seamless, interdisciplinary fashion. The use of a common Web format and the weekly meetings of the instructional team members were both central to this labor-intensive but critically important process of curricular refinement. All of the lectures have now been revamped to fit the Web template, providing an accessible, graphically appealing "textbook" for the course. Forcing all lecturers to conform to the same template assured continuity and integration while retaining flexibility and allowing for future evolution. A complete series of multimedia laboratory modules for Introduction to Global Change I and II has been developed using the Web site for storage, archival, and communication purposes. The Global Change curriculum features several "case studies" in

Figure 10.1. Student Enrollment in the Global Change Course Sequence



which the relevant faculty member applies his or her personal research interest to a topic in global change. Since many of the participating faculty have exciting research programs, the case studies are popular with the undergraduate students.

Mentoring. Mentoring takes place at several levels within the Global Change structure. The students are introduced to between four and six teaching faculty on the first day of classes, and these faculty are available throughout the term by e-mail and in person for student interactions. While often not available for one-on-one counseling, the teaching faculty participates in various informal meetings each term in which issues can be raised and advice sought. The term-project presentations, movie nights, exam review sessions, in-class discussions, and so on all provide additional opportunities for faculty-student interaction. The common "ownership" of the class Web page and the e-mail listserv helps to build a faculty-student relationship that goes beyond the standard lecture model.

The GSIs are very important human resources and the student-GSI relationship represents the front line of the mentoring approach in the Global Change program. Various techniques have been adopted to optimize these interactions, based on results from the evaluation program. These include limiting the size of the lab sections, reducing the cadence of computer labs and interspersing discussion sections, counseling GSIs weekly, providing a teaching manual and a day-to-day calendar for GSI activities, and using one or more experienced individuals each term to act as a group leader for the GSI team. Collectively these adjustments have greatly improved the GSI-student relationship as seen in the evaluation instrument devoted to this interface.

In general, the experience of the University of Michigan Global Change course sequence has been very encouraging. The majority of the GSI appointments are now institutionalized and the Global Change program is in the process of being expanded to develop the first interdisciplinary minor at the University of Michigan. The evaluation results (summarized at http://www-personal.umich.edu/~dey/ucdt) point to increased student engagement, learning, and satisfaction as the Global Change courses have been revised over time. The use of several instructors from different disciplines appears to contribute to students' ability to understand global change concepts, while potential transition problems have been minimized by careful coordination within the instructional team. It is believed that a significant component of the success of the Global Change sequence has been due to the emphasis placed on those elements of effective mentoring summarized in Table 10.1.

Summary

The importance of well-designed introductory science courses is generally accepted due to the significant impact that such courses can have, for good or bad, on subsequent student careers. Science-based courses can be configured to provide the kind of nurturing and mentoring environment that has proved to be successful in the more intimate formats afforded by undergraduate research opportunity's UROP. With careful evaluation, and with an appropriate level of institutional commitment, science-based, interdisciplinary, introductory courses such as the University of Michigan's Global Change sequence can indeed serve to enhance the overall student experience by providing a rich, supportive learning environment.

References

Artique, M. *The Teaching and Learning of Mathematics at the University Level: Critical Questions for Contemporary Research in Education.* Monthly Notices of the American Mathematical Society, December 1999.

Clinton, W., and Gore, A. *Science in the National Interest.* White House Policy Statement, August 1994.

Coalition for Education in the Life Sciences. *Professional Societies and the Faculty Scholar: Promoting Scholarship and Learning in the Life Sciences.* University of Wisconsin, 1999.

Lloyd, B. (ed.). *New Directions in General Chemistry.* Washington, D.C.: American Chemical Society Division of Education, 1994.

Nagda, B. A., Gregerman, S. R., Jonides, J., von Hippel, W., and Lerner, J. S. "Undergraduate Student-Faculty Research Partnerships Affect Student Retention." *Review of Higher Education,* 1998, 22(1), 55–72.

National Science Board. *Failing Our Children: Implications of the Third International Science and Mathematics Study.* Washington, D.C.: National Science Board, July 1998, NSB 98–154.

National Science Foundation. *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering and Technology.* Report of the Advisory Committee to the National Science Foundation's Directorate for Education and Human Resources. Washington, D.C.: National Science Foundation, 1996, NSF 96–139.

National Science Foundation. *Shaping the Future, Volume II: Perspectives on Undergraduate Education in Science, Mathematics, Engineering and Technology*. Report of the Advisory Committee to the National Science Foundation's Directorate for Education and Human Resources. Washington, D.C.: National Science Foundation, 1998, NSF 98–128.

National Science Foundation. *Preparing Our Children: Math and Science Education in the National Interest*. Washington, D.C.: National Science Foundation, Mar. 1999, NSB 99–31.

Physics Education Research: A Supplement to the American Journal of Physics, Supplement 1 to Volume 67, No. 7, July 1999.

Tinto, V. *Leaving College: Rethinking the Causes and Cures of Student Attrition.* (2d ed.). Chicago: University of Chicago Press, 1993.

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