Global Change I Course: A Technology-Enhanced, Interdisciplinary Learning Environment

at the

University of Michigan

by

The Institute on Learning Technology

part of the

A Project of the Wisconsin Center for Education Research

National Institute for Science Education

Funded by the National Science Foundation

Andrew Beversdorf (abeversd@students.wisc.edu), M.A.,
Susan Millar (smillar@engr.wisc.edu), Ph.D., and
Jean-Pierre R. Bayard (bayardj@csus.edu), Ph.D

Spring 2000

This case study also is available from the
Learning Through Technology web site,

Acknowledgements: The authors thank the University of Michigan faculty, staff, and students who participated in this study. These individuals very graciously responded to our request for their time and attention. This case study is based on a deeply collaborative analysis and planning process undertaken by the NISE's Learning Through Technology "Fellows" group: Jean-Pierre Bayard, Stephen Erhmann, John Jungck, Flora McMartin, Susan Millar, and Marco Molinaro. The Fellows, in turn, benefited substantially from members of the College Level One Team: Andrew Beversdorf, Mark Connolly, Susan Daffinrud, Art Ellis, Anthony Jacob, Kate Loftus-Fahl, and Robert Mathieu, Sharon Schlegel.
Reader’s Guide

When the words “Global Change” appear in capital letters, they refer to Global Change I, Physical Processes (UC 110), the first course in the University of Michigan’s 3-course Global Change minor.

Special terms appear in the Glossary. The first time one of these terms occurs in a major section, it appears underlined and the definition is available in a mouse-over box. These definitions appear as lettered footnotes.

All citations to which the case study refers are listed in the References.

Technical asides are indicated by a numbered footnote marker and available to the reader in a mouse-over box. These asides also can be found in the Endnotes.

Lengthy quotes from participants that illustrate a point often are available in mouse-over boxes (and also as lettered footnotes), for the benefit of the reader who prefers to read the participants’ own words.

Various topics introduced in the study are developed at greater length in Discussions (specified by number) to which the reader is referred at relevant points.

The reader is referred at relevant points to various other Resources (specified by letter). Among these is a short description of the Methods Used to Produce this Case Study (Resource B).

Of note for users of the web version: Clicking the “previous page” button will take you to the previous linear section of the case study, not necessarily to the page which you last visited. Clicking the “back” button of your web browser will return you to the section last visited.

We use pseudonyms for the students who appear in the quoted material. To help avoid confusion, the researchers are identified as “interviewer” the first time their voice appears an interview segment. Lengthier quotes appear in italics.

The instructors and administrators who are identified in the case study read the document and gave us permission to use the quotes we attribute to them. These U of M readers also affirmed that this case study conveys the essence of what they were doing in the Fall of 1999.
Introduction

Ben van der Pluijm
Director of the Global Change Project (2000 – )

“Many of these [Global Change students] will go on to be lawyers, politicians, or whatever they want to be, and they will make major decisions that affect our lives. To do this right, they will not only need to read and write, but also think about the material that is given to them. That’s what we want them to do in Global Change, teach them to be critical thinkers about the world around them.”

Timothy Killeen
Director of the Global Change Project (1992-2000)

“We think that all students should be exposed in a quantitative, robust way, to the science basis of our evolving understanding of the human relationship with the earth system. And that involves a lot of complexity, a lot of issues, and it’s a big panorama. Society is going to have to make decisions on the basis of knowledge and the ability to process information, to understand limitations of knowledge, how to evaluate the errors of systems, where uncertainties might arise, and how you can draw on tools from different disciplines to solve real-world problems.”

What is the Global Change I course?
Tim Killeen, Ben van der Pluijm and several other faculty at the University of Michigan-Ann Arbor have designed and teach Global Change I, a team-taught, interdisciplinary course that focuses on the complex, related factors that affect the world. These factors include, among others, chemical, biological, ecological, and astronomical phenomena, as well as sociological and economic issues. Global Change I is a 4-credit course that has no prerequisites and enrolls some 170 students each fall term. It serves predominantly first- and second-year students, and fulfills natural science distribution requirements. It is the part of a three course curriculum that forms the core of a minor in Global Change.
The topics of study addressed in Global Change I include: origin and evolution of the universe, solar system, and the Earth; origin of the elements; geological processes; the Earth's atmosphere and oceans; chemical and biological evolution; origin and evolution of life; life processes; biogeochemical cycles; ecosystems and ecosystem dynamics; atmosphere-biosphere interactions; paleoclimate; sea level changes; climate change and global warming. The course introduces interactive dynamical modeling.

**Why take on all the extra work for a team-taught interdisciplinary course?**
The Global Change faculty reasoned that, while students could learn about each of these areas in separate classes, they would learn about global change in a more meaningful way if the faculty themselves demonstrated the interconnectedness of these subjects. Moreover, the Global Change faculty felt a course of this type would provide students—regardless of their planned majors—a powerful way to learn about science.

**What’s so special about this course?**
Drawing on material and computer-based tools from their respective academic areas of study, and on the expertise of guest lecturers from the social and natural sciences, these instructors seek to synthesize a broad array of knowledge into what one student called a “melting pot” of ideas about global change. To facilitate this synthesis of ideas, the Global Change faculty have constructed a computer-enhanced learning environment. As part of the course requirement, students spend between one and two hours a week in a computer lab where they use two interactive software programs: **ArcView**, a geographic information system, and **STELLA**, a geographic modeling program. With this software, students experiment with the dynamic, interrelated factors that affect global change. George Kling, a biology professor, calls these labs an environmental “test tube” where students are able to, among other things, simulate the effect, around the globe, of increased population, and to visualize the worldwide impact of chlorofluorocarbons (CFC) emissions.

**What goes on in the Global Change I course?**
Students in the Global Change I course learn through the following key activities:

- **Lectures.** Three hour-long lectures per week, presented by the Global Change faculty, with occasional guest lecturers.

- **Readings.** Lecture notes on the course website (http://www.sprl.umich.edu/GCL) serve as both the textbook and “coursepack,” and also connect students to material available on other websites. Material in the lecture notes is not identical to that presented in class. The course website also presents lab materials and assignments, Quicktime movies, the course syllabi and outlines. Materials on the Web are updated frequently. The instructors expect students to keep current on the web material, and to check email for news and information about the course, such as links to relevant information sources. Supplemental reading material is occasionally distributed in class. There is no cost for course materials except when students choose to print from the web.
• **Lab/Discussion.** A lab/discussion section meets for two hours per week in a discussion classroom or computer classroom, and is led by a graduate student instructor (GSI). Student participation in these sessions is mandatory. Each lab/discussion session is worth 15 points (attendance and participation - five points, assignments - ten points), and together these sessions count for approximately 25% of the final grade.

Laboratory sessions involve use of the dynamic modeling program **STELLA**, an easy-to-use, yet powerful, graphics-based program that allows students to investigate global change issues such as ozone depletion, population growth, and the greenhouse effect. Lab assignments generally consist of answering a series of questions that are submitted to and reviewed by the GSI the following week.

During discussion sessions the students and GSI explore issues covered in lectures, view movies, and go on short field trips to campus resources (e.g., the Natural Science Museum). Discussion sessions usually include a short assignment due the following week.

• **Projects.** In both the Global Change I and Global Change II courses, teams of 2-3 students develop a term project, leading to the development of a web-based poster that involves the creation of a website, which is presented at the end of the semester. (Details on how projects are developed appear in the syllabus, http://www.sprrl.umich.edu/GCL/globalchange1/fall2000/syllabus/gc1_syllabus.html.)

• **Tests.** Students take two one-hour midterm exams and a two-hour final exam. The tests, comprised of a mixture of multiple choice and short-answer questions, examine material from the lectures and required readings (both on-line and handouts).

**Evaluation and Grading**

• **Evaluation Activities.** All students are expected to participate in evaluation activities (short questionnaires and web assessments) designed to continuously improve the course.

• **Grading.** A point system (800 points) is used to assign grades:
  - Midterms: 100 points each
  - Final: 150 points
  - Lab/Discussion Sessions: 15 points each
  - Participation: 50 points
  - Assignments: 25 points each
  - Term Project: 150 points

**How do students respond to the Global Change course?**
Very favorably. The students we interviewed told us that this interdisciplinary course taught them not to analyze environmental phenomena in isolation, but rather as a set of interconnected parts of a whole.
**Beth:** If you really sit down and you look at how everything is connected to everything else, [you see] that there will be an effect. Sometimes it'll be positive, and sometimes things that we think are going to be the most negative might not turn out to be that negative at all. And everything just might end up working itself out just because of all the inter-relationships.

**Amy:** As a result of this course, you don't just hear something and assume that it's fact. You hear something and say, “Why would they say that? What does that mean? Where did they get that information?” And then, “What about the other side?”

The computer-enhanced features of the course received as favorable a review as the course overall. Students resoundingly affirmed that the course’s computer-dependent activities fostered meaningful learning by allowing them to work with and manipulate data as opposed to just memorizing it.

**Laura, Global Change alumna:** I think that learning is enhanced by a student taking raw data and making a graph rather than just looking at the finished product. It'll mean less to them and they won't retain it. And I can tell you that because of my own experiences. I knew a lot more about the carbon cycle after constructing a model, playing with it, and manipulating it than I ever did by memorizing the relationships.

**Ruth:** If you're just in a science-based major and you don't like the way the results come out, well, “If I tweak this number a bit, it will come out to this number right here.” Whereas if you're using something like a modeling program, you're saying, “Well, if I tweak that number, yeah, this will come out right, but it's still affecting how everything else is viewed as well.” And if you're just using the pure common numbers, you're not going to see it.

**Beth:** I think [these activities] could have been done on paper. I just don't think it would have been as effective. When we did the STELLA models we actually put them together. Our GSI [graduate student instructor] would show us how, but we actually did it. We actually would connect things to what our GSI would ask us. If we would have done that on paper, it wouldn't have been us doing it. It would have been the professor.

Global Change students not only praised the course during our interviews, but also in their course evaluations. The results of these evaluations corroborate the Global Change faculty’s notion that their course provides an environment in which students learn about global change in meaningful ways. For example, in their responses to the surveys, students report strong cognitive gains. In the Fall of 1999, over 90% agreed or strongly agreed that: a) they learned a good deal of factual material in the course, b) the knowledge they gained improved their ability to participate in debates about global change (Figure 1), and c) the course encouraged them to think critically about global change.

---

These data were gathered, analyzed, and provided by an evaluation team led by U of M professor of Education, Eric Dey and colleagues.

Students were asked to respond to statements by indicating one of the following choices: strongly agree, agree, neutral, disagree, strongly disagree.
The students also reported strong positive responses to the lab component of the course. Eighty percent of the respondents either agreed or strongly agreed that lab assignments were both carefully chosen and intellectually challenging. While only just over 50% of respondents indicated that laboratory assignments made an important contribution to their understanding of the topics discussed in lecture, over 60% agreed or strongly agreed that ArcView helped them understand Global Change concepts and principles (Figure 2). Over 90% agreed or strongly agreed that they felt confident in their ability to use ArcView to construct models. And over 80% agreed or strongly agreed that ArcView helped them understand the relationships among different variables.
When asked about the personal growth experienced from Global Change, students once again responded favorably. Over 90% of the respondents agreed or strongly agreed that they had deepened their interest in the subject matter of the course (Figure 3). Over 80% agreed or strongly agreed that they were enthusiastic about the course material. Over 50% agreed or strongly agreed that they have had opportunities to help other students learn about global change issues. And over 80% said they felt empowered to act on what they learned.
In short, students who take the Global Change course leave with a new way of thinking about, and acting on important environmental issues.

Wow! How can I develop a course like that? The Global Change faculty’s story may sound simple, but the truth of the matter is that creating an interdisciplinary course like this entails a host of challenges. Through the following links, we offer you a more complete and comprehensive story of the U of M faculty’s efforts to help students gain a new understanding about global change.
I. Setting

Note: For useful tips and information on how this case study is organized, please see the Readers Guide.

This case features the University of Michigan-Ann Arbor’s (Resource A. Institutional Context) interdisciplinary team-taught science course called “Introduction to Global Change I: Physical Processes (UC 110).” To read a brief overview of the activities of the Global Change I course, see the Introduction. This course is part of the University of Michigan (U of M) “Global Change Program,” which consists of three interdisciplinary, team-taught courses that examine the topic of global change from physical and human perspectives. All three Global Change courses are designed for first and second year students who want to understand the historical and modern aspects of Global Change. Global Change I, II, and III also comprise the three required courses in the University of Michigan’s recently-approved 17-credit Global Change minor. The GC minor is open to all students except those minoring in Biology or the Residential College’s Environmental Studies.

The Global Change I, II and III courses evolved through a grass-roots effort involving mostly senior faculty from five U of M schools and colleges (most notably the School of Natural Resources and Environment), some ten departments (most notably, the Department of Biology, Department of Atmospheric, Oceanic, and Space Sciences, and Department of Geological Sciences), the Space Physics Research Laboratory, and the national network of faculty known as the Earth Systems Science Education (ESSE) program funded by NASA.

A significant recent development for the Global Change Program is that it has recently been institutionalized. Originally, Global Change was designed without any departmental home in the University and, therefore, faced many obstacles to both funding and staffing. Because Global Change had no departmental home, its faculty had to cobble together a course budget each year, drawing heavily on external resources. Moreover, teaching in the courses for many faculty reflected an overload. However, when we last talked to Ben van der Pluijm, he told us that Global Change Program now receives “significant support from the University (line item in provost’s budget for an initial 3 years)” and received a 100% match on external funding that the course obtained from the W and F Hewlett Foundation. The institutional support also includes some summer salary for long-term faculty recruitment and some teaching compensation.

Since the time we began researching this case study in the winter of 1999 (Resource B. Methods Used to Produce this Case Study), the three-course Global Change sequence was approved as the core of a minor at the U of M. Ben van der Pluijm, geology professor and director of the Global Change Program, calls the minor a “front-loaded” degree program, because it allows students to complete the requirements in the first few years of college. The program substitutes for a portion

---

1 Of note, UC110 is cross-listed as AOSS 171, BIOL 110, GEO 171, NRE 110.

2 In addition to the GC-I, II, and III courses, the GC minor requires two electives, chosen from some 25 courses offered by Atmospheric, Oceanic and Space Sciences, Biology, Geology (in the College of Literature Science and Arts) and the School of Natural Resources and Environment.
of the liberal arts requirements using an integrated natural and social sciences approach. As of Spring 2001, over 30 students were enrolled in the Global Change minor.

Dramatis Personae

The Global Change faculty seek to provide a team-taught course that “seamlessly integrates material.” To this end, they maintain a high level of interaction with each other, attending weekly meetings with the GSIs, bi-weekly team meetings, and each other’s lectures, and participating in summer workshops, among other things. They all have agreed to conform to a single format for presenting material, produce extensive web notes, and design hands-on experiences for the students.

In January 1999, when we studied their efforts, these instructors included:

Dr. Ben van der Pluijm, geology professor, College of Literature, Science and the Arts. Ben has been at U of M since 1985, where his research focuses on the deformation of minerals and rocks. His group uses state-of-the-art laboratory facilities to study the deformation of regions around the world. Whereas some projects are of immediate societal relevance, he is a strong proponent of curiosity-driven research. His professional efforts involve significant editorial duties, whereas his educational interests focus on science education to undergraduates.

Tim Killeen, professor of Atmospheric, Oceanic and Space Sciences, College of Literature, Science and the Arts. Dr. Killeen is the director of the National Center for Atmospheric Research (NCAR) in Boulder Colorado and Senior Scientist at NCAR's High Altitude Observatory. Prior to taking on this responsibility in July 2000, Dr. Killeen was a faculty member in the College of Engineering at the University of Michigan (UM), Ann Arbor, where he taught many undergraduate and graduate classes. He also served as UM's Associate Vice-President for Research, with responsibilities for integrating undergraduate research and education across the spectrum of disciplines. Dr. Killeen was the course director for the UM Global Change sequence from 1993 until his departure from the university.
Dave Allan, professor, School of Natural Resources and Environment. Dr. Allan received his B. Sc. (1966) from the University of British Columbia, Vancouver, Canada, and his Ph.D. (1971) from the University of Michigan. He served on the Zoology faculty of the University of Maryland until 1990, when he moved to the University of Michigan where he currently is Professor in the School of Natural Resources and Environment. Dr. Allan specializes in the ecology and conservation of rivers. In his research he works with colleagues from other disciplines to examine how changes in land use affect the status of rivers and watersheds in both North and South America.

George Kling, biology professor, College of Literature, Science and the Arts. Dr. Kling received his Ph.D. from Duke University in 1988, where he studied the aquatic ecology of lakes in Africa, and worked at the Marine Biological Lab in Woods Hole from 1988-1991 as a postdoctoral researcher, where he studied aquatic ecology in arctic environments. He is interested in how the cycling of elements such as carbon, nitrogen, and phosphorus underlie our understanding of the broad environmental problems of acid rain, eutrophication, species introductions, and climate change. The general goal of his research and teaching is to better understand what controls important ecosystem functions, to relate this understanding to major environmental problems, and to communicate this knowledge to students and the public at large.

Lisa Curran, Assistant Professor, School of Natural Resources and Environment. Dr. Curran received her BA in Anthropology from Harvard University and her Ph.D. in Ecology and Evolutionary Biology from Princeton University. Her professional experience includes over 15 years of interdisciplinary problem-solving and consultancies in South and Southeast Asia working for US Agency for International Development, World Bank, Asian Development Bank, UNESCO-MAB and several international and regional non-governmental conservation organizations. Her research and teaching combines ecology, land use, resource economics and forestry policies with conservation of biocultural diversity primarily in Indonesia. She held an interdisciplinary faculty position at the University of Michigan (School of Natural Resources & Environment, Dept of Biology and Center for Southeast Asian Studies). Currently, Dr. Curran is an Associate Professor at the Yale School of Forestry and Environmental Studies.
Patrick Livingood, graduate student instructor, School of Natural Resources and Environment. Patrick is a Ph.D. student in anthropological archaeology. He has a B.S. in Computer Science and a B.A. in anthropology. His primary research focus is on the prehistory of southeastern North America. Archaeologists are necessarily interdisciplinary, using physical science techniques to generate information, which they interpret as social scientists. In addition, he utilizes GIS and computer simulation in his own research, so he was familiar with both the tools and the goals of the course.

David Halsing, graduate student instructor, School of Natural Resources and Environment. Dave earned a Bachelor's Degree in Human Biology from Stanford University and is currently completing his Masters of Science degree in Resource Policy and Management at U of M. He is studying integrated approaches—science, economics, risk management, and optimization—to natural resource issues. He also spent several years as an on-site trainer for computerized medical technology systems. The experience he had teaching people how to use computers was a huge help in working with Global Change students.

II. Learning Problems and Goals

A. Problems Motivating U of M Faculty to Develop the Global Change Course

- Students are “running away” from science because it is not seen in a relevant context.
- Students have a fear of science.
- Academic community has overlooked global change issues for too long.
- Students do not see technology as an educational tool.

According to many of the University of Michigan faculty with whom we spoke, the Global Change course began as an attempt to provide a more relevant context in which students learn science. A group of U of M professors realized that there was a problem with teaching science as a series of titration labs, carbon cycles, and mathematical formulas that appear to have no relation to anything outside of the classroom. Ben van der Pluijm, a geology professor, told us that teaching these things in a setting void of relevant context contributes to what he calls “the running away as fast as students can from science.”

George Kling, biology professor, attributed this exodus to a fear and to students’ misconception that science is just an amalgamation of

---

a Tim Killeen, professor in the Department of Atmospheric, Oceanic and Space Sciences: “Students get turned off to science forever by getting frustrated over some titration experiment that they can’t handle, or getting thrown too much math. And those students then, for the rest of their lives, are phobic about science.”

b Ben van der Pluijm, professor of Geology: “I am very concerned about what I see happening: the running away as fast as students can from science. And I’ve realized you don’t fight it by just giving them more science; forcing more science on them is not going to work.”
abstract concepts and numbers. These U of M faculty decided that global change, an area that Dave noted had been ignored for too long by the academic community, could provide a more meaningful context for science instruction.

Lisa Curran, also a professor in the School of Natural Resources and Environment, told us that although the current generation of students is relatively technologically savvy, they are still not fully aware of the power technology has as an educational instrument.

B. Learning Goals the U of M Faculty Seek to Achieve

- Provide a relevant context in which to teach science.
- Bring the previously neglected issue of global change to center stage.
- Dispel student fear of science by showing that it is just common sense.
- Get students to think independently and critically about global change issues.
- Provide technology as a tool to foster independent and critical thinking.

The U of M instructors established a set of goals to address the problems spoken of in the previous section. For instance, to address the problem of providing a meaningful context for science instruction, the faculty told us that they needed a new angle, something that “makes it relevant again, like it was in the sixties when we put a man on the Moon.” The U of M faculty felt that by focusing on vital environmental problems, they could create a compelling,

---

\(^c\) George Kling, biology professor: “So, one of the things that I have noticed, especially with the freshmen and especially in this course that has no science prerequisites--no math, no chemistry, none of that--is that they are very afraid of science, and don't quite understand what it is all about. . . . I try to tell them that science is just common sense and give them examples from their everyday lives but the problem is that they aren't familiar with the units science uses. So if we say that in the global carbon cycle we can't find 2 billion tons of carbon a year, is that a lot? Well, if we said that 2 billion people a year went missing, does that sound like a lot?”

\(^d\) Dave Allan: “I think what was going on at that time was a tremendous increase in interest in global change of a climate nature around 1988, 1989. I think the individuals involved took a broad view of global change while they were particularly struck by the emerging concern that the climate was warming as a result of human intervention. There were population issues, environmental issues, and a recognition that there was a social as well as a scientific dimension to this. But I think the prime driver, as I looked back over it, was the emerging sense of change at the global level occurring in an unprecedented way and not being addressed in the academic community, either in research or in teaching. That's what I see as the genesis.”

\(^e\) Lisa Curran, professor in SNRE: “I thought students would be much more Web savvy. Many students don't know how to open an attachment. They've never done a library search here. I think there are many skills that we take for granted since there's been this media onslaught showing how technologically savvy these kids are. Maybe they're playing Nintendo, but it doesn't necessarily mean they know how to use this for a learning tool.”

\(^a\) Patrick Livingood, graduate student instructor: “I try to draw out from the students why this is relevant to consider as people, even if they're not going to be scientists. I try to make it relevant to society, even if they're not going to be scientists or use any of this directly. When they see a headline about climate change or spending on forestry, they'll have some sense of what that means and how it matters to them. And I see that as just critical.”

\(^b\) George Kling, professor of Biology, College of LS&A: “I think this is an innovative way to teach science to people who otherwise run away from it, even though their life is going to be filled with science in this century. So my reason for getting involved is driven by wanting a chance to educate students in a very different way, and to make science relevant again, like it was in the sixties when we put a man on the moon.”
meaningful context for science education, and could also address the problem that Dave spoke about in the previous section—the academic community's failure to address global change issues. Tim Killeen, for example, thinks that the Global Change initiative will mitigate this failure and will, hopefully, inspire institutions like the University of Michigan to require students to take a course on environmental issues as a requirement for earning a degree.

Another problem that the U of M faculty pointed out in the “problems and goals” section is that students often express fear of science because they see it as just a series of abstract numbers and formulas. George Kling, therefore, made it his goal to “dispel that fear” by pointing out to students that, “in your daily life, certain things make perfect sense” and that is “exactly the same way science works.” Tim Killeen expressed a similar sentiment saying that the goal of the course is to open students’ eyes to science so they would use science as a “tool” instead of a “club.”

Finally, in order to address their students' failure to see technology as a useful educational tool, the Global Change faculty made it their goal to introduce their students to technology in ways that would facilitate meaningful learning by letting students “examine material...and come to

---

Amy, Global Change student: “I think in the area of goals, mine and the faculty's are the same. And that is, it will be my generation's responsibility to deal with this. It's essentially a crisis of the way that humans interact with the environment because we haven't been really respectful of the environment. We think we have this control over it, and so the point of the class I think is not to just show you the past 50 years and how we just hurt the environment. It's about starting at the very beginning of time, which is what we did last semester. We started with Big Bang theories and are working through to understand how the environment works, how we've impacted it.”

Beth, Global Change student: “They want to show us what we can do to change things when they become problems, what we shouldn't change, what problems are important, what problems are really a crisis, and what problems really aren't problems.”

Tim Killeen, professor of Atmospheric, Oceanic, and Space Science: “We think that this program might ultimately reach a point where it is a requirement for all students to take 'a human relationship with the planet' course, and that you shouldn't be able to get a degree from the University of Michigan unless you have an appreciation for the implications of this relationship. You should know what's going on. You should know what's happening with the water resources, with land use, with soil quality, the impacts of industrialization, of migration, with the role of conflict resolution, all those things that are happening. And ultimately we'd like to tie this into the humanities, ethics, and so on. That ought to be a foundation for a university degree, and I think that if Michigan could really pull that off, it would be very distinctive.”

George Kling, biology professor: “One of the things that I want to get across to them is that they can be independent thinkers and use the tools of science in order to evaluate questions or problems. And it is not necessarily just with science, but I can use examples that come from all walks of life and ask them to apply scientific principles to anything that is happening in their lives. So I try to dispel that fear of science and tell them that science is just common sense, and give them examples of how in your everyday life, certain things make perfect sense. I ask them, 'How many people would agree with this?' Well, of course they would agree. And then, well, that's exactly the same way science works. It's just a matter of assembling some information that is common sense. All they have to learn is the weird numbers.”

Tim Killeen: “Our vision is that students who go through such a course will have their eyes open, will have tools, won't be afraid of science. They won't use science as a club, but as a tool to support a problem-solving outlook on the world. And there are jobs in every walk of life that can be enriched by this perspective. That is the responsibility of a research university—to do that by infusing research elements into the course.”
conclusions on their own” with “essentially the same software and the same data that any professional social scientist would use.”\(^{\text{b}}\) By putting the responsibility of learning into the hands of the students, they hope to make them more “independent,\(^{\text{i}}\) critical thinkers.”\(^{\text{j}}\)

\(^{\text{g}}\) **Dave Allan:** “I see the technology as being all sort of linked with the learning gains. I don't see the technology as an end in itself, but it is a terrific enabler of what we want to do.”

\(^{\text{h}}\) **Patrick Livingood, GSI:** “I'm glad the technology gives them a chance to tinker with the idea they've been given, and play with the data they've been given, and get some confidence. They can begin coming to conclusions on their own, especially this semester with **ArcView.** I mean, they're using essentially the same software and the same data that any professional social scientist would use. And so hopefully they would just get a sense that they can examine this material on their own. There shouldn't be any barrier for them.”

\(^{\text{i}}\) **Laura,** Global Change student: “One of the goals of the course is to make students more independent. The first lab they show you a picture of what you have to do, they give you step-by-step instructions, and as it gets further and further on in the term, they'll start to tell you, 'Design a model for this purpose,’ but they won't tell you any of the specifics. Or they'd tell you to ‘Use a combination of statistical methods or data from our database to show the relationship between these two things.’ And then you'll have to do it on your own.”

\(^{\text{j}}\) **Ben van der Pluijm,** Professor of Geology, College of LS&A: “Many of these students will go on to be lawyers, politicians, or whatever they want to be, and they will make major decisions that affect our lives. To do this right, they will not only need to read and write, but also think about the material that is given to them. That’s what we want them to do in Global Change, teach them to be critical thinkers about the world around them.”
III. Creating the Learning Environment

The U of M Global Change faculty are among the growing number of faculty who are designing their courses as learning environments. As such, we consider them to be bricoleurs: keeping their focus on their problems and goals, they scan their environment for, and then creatively combine, a set of resources that achieve their goals. To meaningfully examine the Global Change learning environment, we link the problems that motivate these faculty bricoleurs to create alternative learning environments with the goals for student learning that they believe will address their problems.

The majority of learning activities that the U of M Global Change faculty use to achieve their goals are informed by the following teaching principles:

In regard to their first teaching principle, the faculty members believe that students learn most effectively not when teachers act as “authority figures,” but rather when students carry out their

---

*a* A learning environment is a place where learners may work together and support each other as they use a variety of tools and information resources in their pursuits of learning goals and problem-solving activities (Wilson 1995).

*b* “Bricoleur” is a French term meaning, roughly, “handyman.” A bricoleur is adept at finding, or simply recognizing in their environment, resources that can be used to build something they believe is important and then combining these resources in a way that achieves their goals.
own investigation and critical thought processes. Dave Halsing and Patrick Livingood, graduate student instructors (GSIs), articulated this difference by describing an activity that deals with ozone depletion. Dave explained that the students “look at real world numbers concerning CFC production and ozone depletion and we ask them to tinker with the percentage reduction after a certain year. They’re told that they have to keep ozone at a certain level and then they run the model to find out what point it can't dip below.” Patrick Livingood then contrasted this hands-on method with what would be a more passive one, saying, “Someone could have said in lecture, ‘We're going to have to reduce ozone by 99.5% to keep skin cancer rates below this certain number,’ and students would have forgotten about it five minutes later. It would have been a meaningless number.”

Regarding their second teaching principle of enabling learning to occur in diverse ways, the **bricoleurs** feel that teaching the course in an interdisciplinary way is crucial. As Tim Killeen, professor of Atmospheric, Oceanic and Space Sciences (now director of the National Center for Atmospheric Research), stated, an understanding of global change is shaped not by single, separate, tunneled view points but rather by a “panorama” of perspectives involving “a lot of complexity, a lot of issues.”

To help students manage this complexity, the U of M faculty have incorporated interdisciplinarity in all of the Global Change learning activities, whether computer-dependent or computer-independent. The geographic modeling programs that students use in labs entail both social and scientific variables. The lecture sessions feature guest professors whose fields of expertise range from economics to geology. According to Lisa Curran, professor in the School of Natural Resources and Environment, the eclectic range of student interest can vary from those concerned with “community development” to those concerned with “international policy.”

See Discussion A for a student discussion of the interdisciplinary format.

Having students run computer-based **STELLA** models is one of several activities that the U of M faculty use to create a learning environment that implements their teaching principles. These learning activities fall into three separate categories:

---

**David Halsing,** GSI: “It works partly through establishing myself as not an authority figure, but as sort of a guide through the territory. Where they have to walk and carry their own bag, but I can point out some interesting things along the way and make them think about them. For me, it's making them critical thinkers and not handing them anything on a platter. Even when we're doing computer work, I don't want to just say, ‘click this,’ and watch the student. I want them to begin thinking, forming goals. ‘What am I trying to get to next? What do I know? What do I need to do to get there?’ And this is especially important when we're doing a content part where they have to analyze the data they're looking at, not just handing it to them, but guiding them through, and getting them to think responsibly to come up with an interpretation of what they're looking at. That's what I try to do.”

**Lisa Curran,** professor in the School of Natural Resources and Environment: “I see some students that say, 'I'm going to work on community development,' and others who say, 'I want to go into international policy.' I have had students from either Global Change or my undergraduate class that say, 'I'm going to be in the London School of Economics.' Minorities are now in public policy—African American males—who you normally don't see in science courses.”
Computer-dependent activities are activities that would not be possible, or at least not feasible, without computers. In the University of Michigan Global Change course, these activities include labs in which students:

- conduct hands-on analysis with real-world data and geographic information models
- research and critically assess an array of global change issues using on-line literature and data.

Computer-improved activities are activities that faculty believe work incrementally better with technology, but can still be implemented without it. In this course, these activities include web-based lecture notes, simple animations, and other aids that give students material in a uniform format and help them manage the amount of content presented to them.

Computer-independent activities—that is, activities that do not involve the use of computers, include:

- group work
- lectures
- homework

A. Computer-dependent Learning Activities

The U of M faculty employ two learning activities in ways that would not be possible without computers. These activities are:


\(^a\) The Global Change curricula incorporate the programs STELLA and ArcView 3.0 GIS into the pedagogy. STELLA is a software package designed to help students graphically build and control dynamic models. The STELLA program interface lets the user set up model elements (stocks and flows) to specify the relations between the elements, and then project how these elements will react over time. The program serves as a useful and flexible introduction to how computers may be used to model real-world problems and situations. STELLA is an important tool for understanding global change, modeling is the only way to predict the impact of global change. Currently, all
This software allows students to extract global change information from data banks (for example, from the World Resources Institute, using the Internet), and, using this data, to “model global change phenomena and understand the human consequences of environmental change.” Dave Allan, Professor of Natural Resources and the Environment, noted that, “the STELLA program is a terrific enabler of critical thinking about dynamic processes and the GIS software is a terrific enabler in thinking about patterns on the globe.” As George Kling, biology professor, explained, the two interactive software programs allow students to experiment with the dynamic, interrelated factors that affect global change in a computer-enhanced, environmental “test tube.”

This research gives students first-hand training in managing what one central administrator calls “an information explosion,” a skill that is essential to the future of evaluating global change policies.

- Research and critical assessment of an array of global change issues using on-line literature and data. After analyzing this literature and data, Global Change students create their own website on environmental issues. This activity gives students training in managing the information explosion. It also provides them with insight about the credibility of on-line information by showing them how easy it is to put information on the World Wide Web.

The U of M instructors explained that having students use computer-dependent learning activities like STELLA models and ArcView geographic information systems enable students to:

- engage in hands-on application of real-world data analysis, a process that is crucial if students are to understand global change issues in a meaningful way.

Predictions which scientists use for estimating the impact of environmental change on the Earth's future are based on dynamic models, like STELLA. (Quote taken from “Evaluation Plan for Development, Deployment, and Evaluation of an Interdisciplinary Undergraduate Curriculum Development Testbed” A project funded by the National Science Foundation program on Institution-Wide Reform of Undergraduate Education in Science, Mathematics, Engineering, and Technology. [http://www-personal.umich.edu/~dey/ucdt/plan.html](http://www-personal.umich.edu/~dey/ucdt/plan.html).)

b ArcView is a powerful program used in the real world. ArcView 3.0 GIS a computer mapping system designed by Environmental Systems Research Institute, Inc. This geographic information system is designed to help the user to analyze data in a spatial context. GIS technology integrates common database operations such as query and statistical analysis with unique visualization and geographic analysis. ArcView is most often used as a tool by GIS specialist to analyze street networks (traffic planning and maintenance), natural resources (natural resource management, habitat assessment), land parceling (zoning), and facilities management (utility planning and maintenance). ArcView's powerful visual and analytical capabilities have also been used to as a pedagogical tool. (Quote taken from “Evaluation Plan for Development, Deployment, and Evaluation of an Interdisciplinary Undergraduate Curriculum Development Testbed” A project funded by the National Science Foundation program on Institution-Wide Reform of Undergraduate Education in Science, Mathematics, Engineering, and Technology. [http://www-personal.umich.edu/~dey/ucdt/plan.html](http://www-personal.umich.edu/~dey/ucdt/plan.html).)

* Taken from U of M proposal to the Hewlett Foundation.

a George Kling, professor of Biology: “This is just a computer-based laboratory to see what happens. We can’t change the CO₂ concentration in the world in an experiment. We can only do it with models and that, I think, is a step forward in information technology. I think that is probably the most important research tool that we have.”

* Students access this data from a CD-ROM (which is copied onto a server) provided by the World Resources Institute. They are also increasingly accessing data from the Internet.
focus more on learning concepts rather than on doing calculations; and

receive training in the use of tech-enhanced research tools

They described three advantages of having students use technology to collect and analyze data:

- It helps students develop a better understanding of how different phenomena are related (for example, CFC emissions and skin cancer rates) because they investigate the relationship in a hands-on fashion.
- By shortcutting the need for students to focus on technical details of calculations and graphing (a form of cognitive overload), it enables them to focus their attention on the deeper concepts.
- They gain first-hand knowledge of the tools used to achieve this understanding.

Patrick Livingood and Dave Halsing, graduate student instructors (GSIs), describe a lab that encapsulates these three advantages of technology. Students were asked to run a model concerning the real-world reduction in CFC emissions. Because the students themselves calculated the amount of reduction necessary to keep the death rate at an acceptable level, they truly understood the process they were studying. According to the GSIs, merely hearing these same statistics in lecture would not have had the same meaningful impact. Simultaneously, the technology performed mathematical and graphing tasks, thus allowing students to concentrate on the conceptual focus of the exercise.

**Dave Halsing:** They look at real-world numbers concerning CFC production and ozone depletion and we ask them to tinker with the percentage reduction after a certain year. They're told that you have to keep ozone at a certain level and then they run the model to find out what point it can't dip below. And of course you first try 50% reduction and that doesn't get it, 75% reduction doesn't get it, 90% reduction didn't get it. And you keep pushing up and you end up having to put 99.5% reduction to keep skin cancers below a certain level. It was to teach them the difference between emission-based standards versus health rates standards.

And that was a really cool concept for a lot of the students, because they're mostly freshman and sophomores who haven't thought about how policies are written. And so you present everything in emission-based standards. This is how many tons of CFCs you can emit per year. And all of a sudden you come out on the other side and go, “Okay, three hundred thousand skin cancer deaths per year in the U.S. is acceptable, get there.” And for them to think of it that way, it was like the whole world flipped over. It's much more powerful. Someone could have said in lecture, “We're going to have to reduce ozone by 99.5% to keep skin cancer rates below this certain number,” and they would have forgotten about it five minutes later. It would have been a meaningless number.

**Jean-Pierre (interviewer):** When you say, “seeing the results,” what are they seeing?

**Dave Halsing:** They can put in a value and then see a graph where skin cancer cases per year are plotted, for example. And then they say, “Okay, at the end there are still too many deaths.” So they have to change the percentages. . . Without the technology, it'd be a lot more challenging. You certainly wouldn't get through as much material. You'd be spending
a lot more time calculating numbers and producing graphs on your own, assuming you have students with the mathematical expertise to do that.

See Discussion B for a faculty discussion of computer-dependent learning activities.

On their part, the students we interviewed explained that these computer-based activities helped them understand global change systems better by:

1. helping them visualize a working picture of global change processes
2. learning through tinkering
3. providing real-world contextualization
4. helping them develop information management skills

For example, Sally and Amy, Global Change Students, told us that by using STELLA, they got a “working picture” of geographical and chemical processes that is superior to a static representation of those same processes. STELLA, they explained, animates the complex “connections” and “interactions” upon which their understanding of global change issues hinges.

Amy: If you can draw a picture of how all these systems work together—which is essentially what STELLA does—it's like a working picture, and you can get a graph from it. That helped us understand so much more, like the connections between the different chemical systems or elemental systems, like the carbon cycle. I understood so much better after the lab.

Sally: Without the technology, I don't think you’d have been able to see the interactions in the lab. It would have been something that was still kind of vague and that you didn’t understand.

See Discussion C for a student discussion of computer-dependent learning activities.

B. Computer-improved and Computer-independent Activities

The U of M Global Change bricoleurs use three computer-independent activities to achieve their teaching goals. These activities consist mainly of group work, lecture, and homework.

1. Group work

The U of M Global Change instructors use group work for both computer-dependent and computer-independent activities. According to the students we interviewed, group work is encouraged in the lectures and discussion sections but is demanded in the computer labs (See What Goes on in the Global Change I Course? for a description of the key course activities). In the first two settings, group interaction allows students to get feedback on global change issues from a variety of perspectives. In the latter, it allows students to develop both technical and non-technical skills when using the modeling software. In both settings, group work facilitates independent learning. One student, Sally, told us about the importance of having peers in the class who could often explain a concept in a way that “made more sense than what the professor or GSI said.” Because of this, she said it was often unnecessary to ask the graduate student instructor (GSI) or professor a question.
Amy, also a Global Change student, concurred with Sally’s assessment of the importance of group work. She emphasized the way that the eclectic backgrounds and academic interests of the students mirror the interdisciplinary framework of the course. She said that the purpose of group work for her and the other students was not to collaborate with students who had similar majors but to team up with students majoring in anything from pre-dentistry to music, thereby taking advantage of the vast array of viewpoints that were represented in the class.\(^b\)

In the computer labs, the U of M faculty use group work to ensure that every student gets equal experience with the various facets of a given activity. For example, while doing group work with the geographic modeling programs, some students feel more comfortable working on the research aspect of the activity while others are more at home managing the technical factors involved. According to the students we interviewed, the instructors and GSIs require them to split up these tasks.\(^c\)

### 2. Lecture

While the collaborative activities mentioned above are aligned with the instructors’ teaching principles that teachers should shift major responsibility for learning from the faculty to the students, other course activities, like standard lectures, are not yet aligned with that principle. However, even when describing their lectures, the faculty signaled a desire to construct a more “discussive framework,” suggesting that they are considering ways to proceed with the ambitious attempt to consistently implement active learning strategies in the large lecture courses.

One way the U of M bricoleurs have tried to improve upon the more traditional lecture is by providing students with online lecture supplements, which comprise a “computer-improved” learning activity. The Global Change home page (http://www.globalchange.umich.edu) provides

---

\(^a\) Sally, Global Change student: “But the lecture wasn’t like a normal course, it was really relaxed. And you didn’t necessarily have to ask the GSI a question because everybody else in lecture would give you their viewpoint or what they thought a better explanation would be. There’s always someone in the discussion or the lab who could explain. And you could understand it once you got a whole bunch of people’s explanations, you’d always find one that made more sense to you than what the professor or GSI said.”

\(^b\) Amy, Global Change student: “I would say that the people in my lab were a pretty good representation of all the majors here at school. There were people from almost every school, if not every school, mostly from Literature, Science and Arts, but that’s the biggest part of the University. There are many students from Engineering. There are many students in pre-dentistry or pre-med. I’m in the School of Music and also LS&A. We have to work in groups for the projects and very few people say, ‘Well, I’m a poli sci major and you’re a poli sci major, so let’s work together on this.’ We’re all from these different backgrounds, but because the course is interdisciplinary, the students interested in taking it are. And I think that contributes to the class, because you get a lot of different viewpoints, or people come from different backgrounds and share different views on this.”

\(^c\) Beth, Global Change student: “When we work in the computer labs, what tends to happen sometimes is students will group together and say, ‘Okay, one person handles all the Web development, the other person handles research,’ which is discouraged. The GSIs are trying to work with students and trying to get people to collaborate so everybody learns as much about the Web development as they do about research.”

Sally, Global Change student: “After a little while you learn who’s more likely to know what, so you turn to them for different things.”
students with on-line lecture summaries and also provides hyperlinks to websites related to particular lecture topics. Eric Dey, a professor in the School of Education and member of the U of M Center for the Study of Higher and Postsecondary Education, explains that by using the “exact same web material in the lecture that shows up on the web page” they are creating a much “more smoothly organized course.” The students told us that information on the Web provides a good complement to the lecture material because it offers a more dynamic version of a textbook and allows them to explore questions that lead to other questions.

See Discussion D to read a faculty and student discussion of Global Change lectures.

3. Homework
The U of M faculty also use homework as a way to foster active learning. We talked with two students who told us about homework activities that forced them to analyze and critically assess the global change phenomenon of oxygen reduction. They were asked to calculate the harmful effects that cutting down the rainforests would have on global oxygen levels and were amazed to find that, contrary to the message conveyed in the popular media, the loss of the rainforests would have a very small impact on oxygen levels. This epiphany gave them a vivid and new appreciation for the role of science in public policy, an appreciation they might not have gained had they not worked through the answers on their own.

* The following two sentences excerpted from the Global Change website include hyperlinks that encourage students to explore issues more deeply. “The world's population is quickly becoming urbanized as people migrate from rural to urban areas, in search of a better life and better future for their children. In 1950, less than 30% of the world's population lived in cities; by 2025 that figure is expected to exceed 60%.”

b Eric Dey: “Faculty use the exact same material in the lecture that shows up on the Web page which gives students two ways of getting the information. So, increasingly it's become a much more smoothly run course in the sense of having good, nicely formatted content.”

Jean-Pierre (interviewer): “But is ‘more smoothly run’ equivalent to more passive?”
Eric: “I don't think so in this case. I think it's just really more a matter of organization. I think at one level students really appreciate the use of new technologies in the class.”

Sam, Global Change student: “The material that they went through in an hour lecture tended to be really dense. And there's a lot of material. And so on the Web they would have lecture notes. And without that I wouldn't have been able to get as much out of it. I don't think we really had a book. So it was all based on lecture, and personally, I don't think I could have written as detailed notes as they gave me.”

d Amy, Global Change student: “They update the web page every day so if some new discovery comes out, you have that information. It's like the most possibly up-to-date textbook you can have. So, that information can be presented without the computer, but it's nice to have it. And on the website they have links to other science-related websites that you can go to. It's just so much more interactive. You can find what you want, and keep going. You have one question which leads you to another question.”

Amy: “When we are asked the question, ‘Why would cutting down the rainforests be harmful to us?’ The answer seems to be, ‘because of the oxygen we would lose.’”
Beth: “And you would think, because there are so many tropical rainforests, that if you cut them all down, you would lose a large percentage of the oxygen [supply].”
Amy: “That's what we're told. That's the media representation.”
Beth: “But when we actually calculated it, it was such a small percentage.”
Amy: “We thought we did it wrong.”
IV. Outcomes

The faculty who developed and continue to sustain the U of M Global Change I and II (UC110 and UC111) courses participated in the Undergraduate Curriculum Development Testbed (UCDT) [http://www-personal.umich.edu/~dey/ucdt/index.html]. The UCDT was designed to deploy an interdisciplinary curriculum as well as collect data about the interdisciplinary teaching environment at the University of Michigan. It was funded by the central administration of the U of M and an award from the National Science Foundation’s Institution-wide Reform of Undergraduate Education program. Established in 1997, one of the UCDT’s first projects was to field an evaluation team that worked closely with the Global Change core faculty to develop and undertake an evaluation plan intended to provide “formative” information that the faculty could use to improve their course while they were developing it. The evaluation team was led by Eric Dey, professor of Higher Education in the University of Michigan’s School of Education.

Dey’s evaluation team encouraged the Global Change core faculty group to articulate student outcomes, which, in turn, the team used to guide its evaluation activities. The evaluation team gathered data on students’ status as science majors or non-science majors, science preparation, pre-college experiences, course expectations, behaviors, and attitudes. They collected these data by using surveys and cognitive assessments, web-based lab/lecture evaluation forums, interviews, in-class observations, focus groups, Early Student Feedback, and classroom assessment techniques promoted by Cross and Angelo (1993). (See Resource C for more information on the types of evaluation data collected.)

According to Tim Killeen (former director of the Global Change Project, and now director of the National Center for Atmospheric Research), the work that Eric Dey and his colleagues at the UCDT did was indispensable to the success of Global Change. He said that Eric’s regular, critical feedback “helped [Global Change faculty] with all sorts of issues, such as the cadence of introducing new materials into the computer labs, crosscutting themes, transitions between professors, size of lab classes, numbers of discussions, and examples.” According to Killeen, improvements in course organization that resulted from the evaluation process helped make Global Change one of the most highly regarded introductory science courses on campus as evidenced by student evaluations, high enrollment, and interest in the Global Change Minor.

Beth: “People were emailing their GSIs, ‘What am I doing wrong? What’s going on here? This isn’t right.’ When I did it, I was confused. We thought, ‘No. This is just so wrong.’ I thought well, ‘we’re plugging in the right numbers,’ and [the instructor] said, ‘Well, when you did it and the number showed you, why would you think you’re wrong?’”

Amy: “And then in the next class, he said, ‘See? It’s really not important. It’s important, but not because we're going to lose the oxygen.’ I didn't understand that it was chemistry- and science-based, and I thought, ‘I don't get these formulas.’ I didn't know what a mole was. I didn’t take chemistry in high school. So I was like, ‘Whatever.’”

Beth: “I felt like I had returned to sophomore year, and I thought, ‘I don’t know what this stuff means anymore. How am I supposed to use it?’”

Amy: “Exactly. So I wrote a paragraph [on the assignment], and I said, ‘Well, I don’t know, but these numbers seem pretty small… So I think that [the loss of the rainforests] wouldn’t be a big deal… I think we should be more concerned about loss of species and possible medical [effects].’ I received almost full credit because that was the point—to see that the numbers that you hear are meaningless unless you have something else to compare them to. Angelo, T. A. (1993). Classroom assessment techniques: A handbook for college teachers. San Francisco: Jossey-Bass.
Moreover, the faculty lauded the formative role of the evaluation because of its contribution to the improvement of student learning. For instance, Dave Allan, professor of Natural Resources and the Environment, stressed the role of evaluation in determining the amount of work that students did with modeling software.

**Dave:** *We started off with the course thinking that the models and the exposure to this was so important to the students that we needed to give them as much of that experience as possible, because they probably hadn't had it before. What we learned through the assessments and the feedback was that it was too much for them. Instead of having a model every week, now we have a model about every third week. And in between we give them other kinds of exercises that actually help maximize their understanding of the models and their use of that technology. We would have never figured that out. We would have thought, “Oh, these students are grumbling, students always grumble.” But because it was put to us in a very different way, with figures and a clear assessment, we decided, “Okay, we’ve got to change this.”*

The surveys that Eric Dey and his colleagues designed for the computer-enhanced Global Change course seek to determine the degree to which the course fosters meaningful learning. The surveys ask students for:

- their reactions to their laboratory, lecture, and Web experience
- comparisons between Global Change and other U of M courses
- any personal growth they experienced from taking the Global Change course

The results suggest, among other things, that as a result of taking Global Change, students:

- recognize the ability of computer-enhanced laboratories to foster learning
- “think critically about global change”
- “feel confident in [their] ability to gather [web-based] information about global change.
- value interdisciplinary education
- “feel empowered to act on what [they] have learned”

---

*Tim:* *I got really excited, when I could see the course getting better through the evaluation process. We looked at the student ratings at all the large enrollment interdisciplinary courses in science on campus for the last couple of years, and when you take biology, geology, atmospheric science, electrical engineering—the large enrollment, greater than a hundred students, introductory 100-level classes—we outscore them all in terms of the student interest. We get an ‘A,’ the next highest rating is astronomy, ‘A-.’ This is not stuff I talk about normally because it’s sort of a, ‘we’re better than you,’ but for us involved it’s concrete evidence that students regard this course very highly. We’ve seen that in the enrollment, and we think it’s because it’s relevant to their lives.*

**Dave:** *There are several measures of whether we are reaching the students and whether this interdisciplinary approach is worthwhile. The student enrollments are increasing, the feedback that we get from the students in simple questionnaires is very positive. They continue on in the Global Change sequence, they’ve shown enough interest to help us develop a minor in the college. So there are lots of very standard assessment measures and instruments that show that we are on the right track.*
For example, in their responses to the surveys, students report strong cognitive gains. In the fall of 1999, over 90% agreed or strongly agreed* that: a) they learned a good deal of factual material in the course, b) the knowledge they gained improved their ability to participate in debates about global change (Figure 1), and c) the course encouraged them to think critically about global change.

Figure 1. Responses to sample “cognitive gains” question
Global Change I, Fall 1999

The students also reported strong positive responses to the lab component of the course. Eighty percent of the students either agreed or strongly agreed that lab assignments were both carefully chosen and intellectually challenging. While only just over 50% of respondents indicated that laboratory assignments made an important contribution to their understanding of the topics discussed in lecture, over 60% agreed or strongly agreed that ArcView helped them understand Global Change concepts and principles (Figure 2). Over 90% agreed or strongly agreed that they felt confident in their ability to use ArcView to construct models. And over 80% agreed or strongly agreed that ArcView helped them understand the relationships among different variables.

* Students were asked to respond to statements by indicating one of the following choices: strongly agree, agree, neutral, disagree, strongly disagree.
The student survey responses also show generally favorable responses to the lecture component of the course. Over 80% agreed or strongly agreed that having several professors in lectures contributed to their understanding of concepts, and only about 14% agreed or strongly agreed that the transition from one instructor to the next interfered with their ability to learn. However, 74% of respondents disagreed or strongly disagreed that the transition from one instructor to the next interfered with their ability to learn, and 72% disagreed or strongly disagreed that it was difficult to understand how topics covered in the lecture fit together.

The evaluation also showed that students valued their work with the Global Change website and the World Wide Web. Over 80% of the students agreed or strongly agreed that using the Web made a significant contribution to their learning. Forty percent said that links from the Global Change website to other internet websites provided them with helpful information, while 50% were neutral on this issue. Over 90% agreed or strongly agreed that they felt confident in their ability to use the Web to gather information about global change, and 60% agreed or strongly agreed that they used the web skills they learned in Global Change in other classes, and to investigate areas that interested them.

When asked about the personal growth experienced from Global Change, students once again responded favorably. Over 90% of the respondents agreed or strongly agreed that they had deepened their interest in the subject matter of the course (Figure 3). Over 80% agreed or strongly agreed that they were enthusiastic about the course material. Over 50% agreed or strongly agreed that they have had opportunities to help other students learn about global change issues. And over 80% said they felt empowered to act on what they learned.
V. Implementation

During our interviews with the U of M faculty we learned that the same characteristics that make interdisciplinary education a powerful teaching method can also make it an implementation headache. Although not every obstacle the Global Change bricoleurs face is due to the interdisciplinary nature of the course, the majority are.

The University of Michigan is not unlike other research universities when it comes to interdisciplinarity. It has strong academic departments that exert considerable influence over faculty scholarship. The majority of the faculty confine themselves to disciplinary activities. As faculty mature in professional rank, some faculty experiment with inter-departmental research and teaching. There are many examples of faculty who have formed inter-
departmental teaching and research teams. The evidence seems to indicate that this kind of grassroots organizing is the dominant form of extra-disciplinary activity.

In this section, we discuss the personal characteristics—such as a willingness to participate in a grassroots effort—a that faculty need in order to overcome the unique implementation impediments that accompany interdisciplinary education, and more common implementation issues that go along with the creation and maintenance of any computer-enhanced learning environment.

A. Personal Resources

According to the faculty bricoleurs at the University of Michigan, the Global Change course would not be a success if not for the personal qualities of the people involved in its creation. Among these are leadership—a and a willingness to engage in what Dan Mazmanian, dean of the School of Natural Resources and Environment, called an “uphill effort.” The instructors involved with the program constantly come across financial, organizational, and technical problems. According to Bob Owen, associate dean of Literature, Science and the Arts, to overcome these problems you need “committed faculty. I think without that, forget it. You really need people who are committed to put the effort into making it happen.” The success of Global Change depends on the faculty’s recognition that interdisciplinary education is what Ben van der Pluijm calls a “bottom-up” endeavor (i.e., one that is initiated and led by committed instructors). The faculty must demonstrate through their own efforts that their ideas are good and feasible to implement, and then seek support from administration at all levels—from the departments to the provost.

To read a faculty discussion of the personal resources needed for initiating and maintaining the Global Change course, see Discussion E.

---


*a Central administrator: “I think it is fair to say that the Global Change Project has been a rising concern, a grassroots concern—grassroots in the sense of the level of the faculty. We're concerned both about the quality of students in the classroom, the level of preparation, and how well the university is acquitting this fundamental part of its mission, its academic mission of teaching undergraduates. So this is a way in which this has been a percolation upward, which is a good, the best way to have an institution respond.”

*a Dan Mazmanian, dean of the School of Natural Resources and Environment: “All of the instructors contribute to the program, but Tim Killeen turns out to be just one of these unusual people who makes things happen. Leadership matters. The older I get, the longer I'm around, the more I appreciate in a hundred little ways that leadership matters. Someone else could step in, but right now Tim's that leader.” [Researchers’ note: Professor Ben van der Pluijm assumed this leadership role as of spring 2000, when Professor Killeen left the U of M to become the director of the National Center for Atmospheric Research in Boulder, CO.]

*b As of fall 2000, Dan Mazmanian has been the C. Erwin and Ione L. Piper dean and professor of the University of Southern California’s new School of Policy, Planning, and Development.
B. The Unique Implementation Issues of an Interdisciplinary Course

1. Time and workload pressures and the special role of teaching assistants

Many of the faculty members told us that it takes more time to teach in an interdisciplinary course sequence like Global Change than it does to teach in a single disciplinary course. The main reason for this is that the organization of the course depends on the chronological coordination and synthesis of many different topics over the course of an entire semester. For example, George Kling, professor of biology, told us about an instance where one of his colleagues, Ben van der Pluijm, geology professor, was planning to include information about oxygen in the earth’s primordial atmosphere in one of his lectures. However, because a different faculty member had not yet presented material on the evolution of life (an event that predates atmospheric oxygen), Ben was forced to restructure his lecture. It is these types of organizational “disconnects” that lead to what George called an “inherent inefficiency” in team teaching, and contribute to the increased amount of time instructors must devote to such courses.

To minimize this problem, the graduate student instructors (GSIs) have taken on the responsibility of repairing these disconnects and synthesizing the diverse material. While the professors provide the disciplinary ingredients for the course, the GSIs turn these ingredients into what one Global Change student called a “melting pot” of ideas. Creating this melting pot requires GSIs to learn about academic subjects outside of their primary field of study. As George Kling pointed out, in order to adequately answer student questions in lab (the main venue for student-instructor interaction), GSIs need to know “economic models as well as psychological, geological, biological and social models.” George, his faculty colleagues, and the GSIs themselves, expressed concern about the enormous time that it takes to fuse all of these subjects into a coherent whole and, therefore, the importance of having dedicated GSIs who are willing to make an extra effort.

For a discussion of the extra time needed for, and the special importance of the GSIs’ role in Global Change, see Discussion F.

2. Difficulty securing funding

The matter of obtaining regular instructional funding for the Global Change course has been a concern since the course was initiated. One view was expressed by George Kling, biology professor. He believes that it is difficult for “bottom-up” efforts like Global Change to get funding because they must compete with initiatives that come from people higher up on the administrative ladder. Dan Mazmanian, Dean of SNRE, however, said that the reason Global Change has been “barely a blip” in the university budget is that the instructors themselves have been so proficient in finding external funding. George Kling, biology professor, agreed with

---

<c>George: “I think at almost all universities the faculty and student generated issues that come from the bottom up rarely get very much money. Where does the big money go? Oh, the President’s Initiative on this or that. Or the Provost’s Initiative. That’s where the millions, hundreds of millions of dollars go. So we are fighting against that general structure that we have at universities. And we have fought it in part by going outside and getting external funds from NSF, for example. And if we hadn’t been able to do that, no matter what the university says about how enthused they are about this approach, they are not going to support it to the level that it takes to actually do it. So I think that that’s something that everyone has to fight.”</c>
this point but said that if this external money stopped coming through, they [the *bricoleurs*] would need to put more pressure on the administration to provide funding. Finding such sources can also be difficult because of the interdisciplinary nature of the course, according to Tim Killeen, professor of Atmospheric, Oceanic and Space Sciences, in the College of Engineering.

Others whom we interviewed believe that the biggest obstacle to secure funding is that administrators are reluctant to allocate regular funds for the course. This view was presented by Bob Owen, associate dean of Literature, Science, and the Arts, who told us that,

> interdisciplinary programs are almost always more expensive than programs run by a single unit or faculty member, and thus administrators are aware that there is usually a greater risk associated with investing resources in such programs. On the other hand, the potential gains in any academic interdisciplinary venture are enormous if the different components can have a synergistic effect. The U of M Global Change Program is an example of a risk worth taking.

One central administrator also noted that the course is already partially funded, and likely to receive even more support in the future. [Researcher’s note: Since we conducted interviews for this case study, the University has begun to provide considerable support to the Global Change Program]

---

*d Dan, dean of SNRE: “It's actually one of those situations where they have done extremely well on external grants. So there hasn't been a direct cost that's been very significant. They contribute a lot of their time. They're not taxing us.”

_Susan (interviewer):_ It doesn't show up in your budget pages?

_Dan:_ Barely a blip…As a dean, I support it financially and otherwise, but it takes a collection of us to do it, and we only do it because we see the value of what they're doing, rather than doing it just to support an ongoing institutional structure. And whether it becomes institutionalized will, I'm sure, be a question in the next several years. Given the sorting, repositioning and the reorganization, I can't predict where an entity like this ends up residing. If we had a fixed system and I knew all the pieces were fixed for the next five years, I'd say, ‘The logical thing to do is this.’ But, with so many things up in the air, it's not clear what the ‘logical’ thing to do is. So, I think it's going to ride on the momentum, the enthusiasm of the faculty and students for the next several years.”

*e Tim:* “Our thesis is that we were going to take an interdisciplinary approach before we do a disciplinary approach, and we've been turned down multiple times by NSF because reviewers say you cannot do interdisciplinary before you do disciplinary. You've got to get the grounding in the disciplines before you can do interdisciplinary. [Institutional funding works the same way.] We proposed a concentration, or minor, two years ago, and we knew then, on the basis of the student evaluations, that there was a need for that, and that the logical next step would be to put a minor together. We proposed it to the university course committee, and what happened is it didn't have the signature from a particular school or college, so we asked a couple of departments whether they would sponsor it for us and they said, ‘no.’ So, Bob Owen has played a critical role because he opened the door, and in fact, this time when it did get approval, it still did not come with a departmental sponsor, which is the general rule. So, once again, we were breaking new ground.”

*f Central administrator:* “Global Change has received enormous support, you know, as far as GSI positions that have been given. I say this without looking at the budget itself. There has been an enormous release of individual time to cross the borders to participate in this very connective course that brings together Engineering, School of Natural Resources and Environment, and LS&A, especially. The provost has a commitment to the course’s success. But first, she wants to see that it's a valuable contribution, it’s made a difference, and it should go forward. If the deans say that this is a priority for us, and it’s providing a very useful model for other faculty to re-envision their teaching, then it will be supported.”
Project. According to Ben van der Pluijm, the Global Change Project has “received significant support from the University that offers staffing and some summer salary as compensation for extra effort and preparation.” In addition, outside support was obtained from the W and F Hewlett Foundation to develop the Global Change Minor, and matched with funds from several colleges, schools, and the central administration.

3. Financial and personal rewards
The U of M bricoleurs indicated that they receive a lot of personal satisfaction from teaching the Global Change course. They expressed their fulfillment at having changed the way students view science and global environmental issues, and also emphasized their satisfaction at being able to work with and learn from colleagues in academic fields unrelated to their own, teach eager, entry-level students, and pursue a general love of teaching.

However, according to faculty members, one of the main obstacles in implementing the Global Change course is the U of M financial reward structure. George Kling, biology professor, asked and answered the question, “Will the Provost ever offer us a raise for doing this? No. It doesn't look that way.” George and most of his colleagues feel that the reward structure does not adequately recognize their efforts to improve instruction because it does not provide them with appropriate financial compensation for doing so. According to them, this lack of recognition:
1. leads senior faculty members to discourage their junior colleagues from participating in the course;
2. discourages team teaching; and
3. doesn't allow professors to fully prepare lessons for the organizationally demanding courses.

---

a Lisa Curran, professor of the School of Natural Resources and Environment: “You really get to know other people from different disciplines, and you're involved in activities across the university that you wouldn't otherwise seek out. You're exposed to a range of students that is really challenging at first, but you realize that this is a different audience. For example, I'm an ecologist, a tropical ecologist by training, so I find that I have to change how I'm presenting the material. And I have insights into my own work as I give talks for different groups. I think what's really satisfying is the students who come up and say, ‘This is probably the best course I've ever had,’ or ‘This has really changed the way I thought about things.’ You know, it's just this ‘Wow! Okay, I got ten of them out there. I just multiplied myself.’”

***

Patrick Livingood, GSI: “I'm an archeologist so some of this material is new. So I'm learning things. I'm certainly learning a lot about these interdisciplinary courses and administrative discussions than I would never have guessed I would have been privy to. And I'm getting to teach different kinds of material, so I'm learning stuff that way. But I'm also getting some networking value to what I'm doing that may or may not be helpful in the future. There's a lot about this course that I can take away and say, 'These are things that can be improved on, or these are things not to do.'”

b Dave Allan, professor of the School of Natural Resources and Environment: “I saw Global Change as an opportunity in a collaborative way to do something experimental and different in teaching at a level that appealed to me, that entry level in education, like freshmen and sophomores. To me, they're fun students, these really eager empty vessels who are easy to sell on the things I'm enthusiastic about.”

c George Kling, biology professor: “I teach in a number of other courses because I really like teaching in them and I find it extremely difficult to walk away from them. I enjoy the experience and I don't find it easy to turn my back on any of them. So, I think I teach more than I need to.”
To remedy this problem, the faculty members proposed several ways to reform the process by which rewards are given: They suggested that:

1. courses be crosslisted among units;
2. the reward structure not penalize instructors for working outside their department;
3. the university create professorships that recognize excellence in teaching;
4. external reviews recognize teaching efforts;
5. state schools systematically reform their reward structure so that they more closely resemble those of private institutions;
6. the effort for interdisciplinary teaching should be rewarded in a different way from that of disciplinary teaching; for example, teaching credit could be multiplied by a factor of 1.5 or 2 for co-taught, interdisciplinary courses.

It is of interest that members of the administration perceive that the university already is pursuing a number of these strategies for rewarding teaching.

For a faculty discussion, in their own words, of these problems and their ideas for remedying them, see Discussion G.

C. Hardware and Software Implementation Issues

While constructing their computer-dependent learning environment, the U of M *bricoleurs* faced challenges that almost inevitably accompany the implementation of new technology. Tim Killeen, professor of Atmospheric, Oceanic, and Space Sciences, said that it would be “naïve” to think that new technology could come without these types of problems. Eric Dey, professor of the School of Education confirmed that, in the early stages, there were technical bugs. He said that computers would crash, geographic models couldn’t be saved and that students were frustrated by this. To address these problems, the U of M *bricoleurs* were fortunate to have GSIs

---

* This reformation, according to Dave Allan, would require a societal as well as institutional change.

*a A central administrator claimed that teaching efforts are, indeed, factored into the rewards structure. He said, “From the point of view of research, when a faculty member comes up for tenure, the person has to put together a dossier that contains their writing and published work. There is a collection of materials that we put together for teaching. These are basically the raw materials that go before the tenure committee, and there's a great deal of importance placed on the evaluation of the quality of the research, especially from external letter writers from outside the University. Where does this person's research stand among the peers? Is this person going to make an original important contribution to advancing the field that she or he is in? Now in addition to this, what is the contribution of this individual to supporting the teaching mission of this unit? What are the contributions, not only inside the classroom but also how do you see this person reformulating the kinds of teaching? For instance, the Department of Chemistry has, in recent years, undertaken a very serious examination of what they expect an undergraduate major in Chemistry to be.”

*a Tim Killeen: “I think there is perhaps a naïve perception on the part of many faculty that technology equals making things instantly easier, and that's definitely not the case. There's a considerable effort that needs to go into how to incorporate it, what it should be, and to fine-tuning it. And once you're over that, then indeed you begin to see the benefits of it. But I think some people who are not using computers and things like that a lot in their research effort think of it as, 'Boy, this is going to solve a lot of my problems,' and maybe ultimately it will. It would definitely improve the course, but it's not going to be something that's going to take over from day one. You have to really put a lot of effort into it in the beginning in order to realize the benefits down the road. And I think the faculty in this particular course have already done that. They've spent quite a bit of time.”*
with computer knowledge. This knowledge, according to Patrick Livingood and Dave Halsing, the GSIs, really helped them help students “figure out how to work a computer.”

Patrick Livingood: “I was actually a computer science major as an undergraduate. Last semester we used a simulation software, and I wasn’t familiar with that package, but I had familiarity with other types of simulation software. This semester we’re using GIS, and I use that in my own research quite a bit. I didn’t have any specific experience teaching with software, but I’ve worked as a computer consultant, and things like that. So I have experience teaching people to use software.”

Jean-Pierre (interviewer): “How about you, Dave?”

Dave Halsing: “Something of the same actually. I hadn’t worked with the modeling program we used last semester, but for three years I worked for a big medical device company training hospital staff on how to use the CAT-scan and MRI machines that they had just bought. And those are computers, so really what you’re doing is teaching software. So, I had gotten pretty good at helping people figure out how to work a computer, how to understand what the interface meant, and what they were doing when they were setting things up a certain way. So, that part of it was very easy. And as far as this semester, in my previous job at the Geological Survey, I used a really, really intricate GIS. It’s more technical than ArcView, which is sort of a lot more user friendly, a lot easier to learn.”
VI. Summing Up

_Society depends on our citizens’ ability to make wise decisions, which in turn depends on their capacity to process information, understand the limitations of data, how to evaluate the errors of systems, where uncertainties might arise, and how to draw on tools from different disciplines to solve real-world problems._

The Global Change faculty have created a curriculum that provides not only the tools, but also the people and perspectives that students can use to critically analyze the dynamic phenomena that affect the world in which we live. Whether learning about carbon cycles, CFC emissions, global warming, population trends, or any of a host of global change issues, the interdisciplinary nature of the Global Change curriculum helps students consider multiple aspects of a problem—the physical, chemical, biological, geological, and mathematical, as well as the human. They learn to think critically about these various, yet connected, issues from natural and social science professors who themselves are learning to make interdisciplinary connections. From their professors and graduate student instructors, they explore the connections between overpopulation and natural resource use, using modeling programs that demonstrate how emissions contribute to atmospheric changes like ozone depletion and biological effects like cancer. And they learn from their fellow students, who represent eclectic backgrounds and consider global change issues from such varied fields as zoology, engineering, medicine, or even art.

By embarking on and maintaining their vision of the value of interdisciplinarity, the U of M Global Change bricoleurs have learned that the nature of higher education culture and organization is not always conducive to interdisciplinary instruction. These faculty members constantly struggle to strike a balance between the amount of time they spend in their own departments, and the amount of time they spend with Global Change. Although this tension is likely to continue to characterize interdisciplinary efforts on into the future, the U of M faculty have dealt with it by sustaining grassroots determination and a steadfast belief that, as a result of their efforts, their Global Change students are leaving the U of M with much more than just another course, or minor, completed. They carry with them knowledge and habits of mind that will affect generations of posterity.
Discussion A. Students views of the interdisciplinary nature of the GC course

Sam and Robin, two students from the Global Change course, discussed the importance of receiving instruction from professors representing seemingly unrelated fields like atmospheric science and environmental policy. According to the students, these apparently disparate perspectives harmonize in the discussion of changing earth systems by presenting potentially contradictory, yet equally viable points of view that require students to critically think about the connection between the two.

**Sam:** For population growth, they talked about the two leading theories on what’s going to happen with the population—one by Simon and one by Ehrlich—and they're completely opposite. You could discuss them, and though most people always tend to believe one, the other one was just as viable and you could argue it. They taught us to not necessarily argue both, but they showed us that both exist.

**Robin:** I think that has to do with the interdisciplinary aspect of the class. One of the professors is in Atmospheric Science, whereas the other is in Environmental Policy but more conservation biology-based. Those two don’t really go hand-in-hand to the casual observer, and once you get in there you see that what one may suggest, the other may contradict. That was one thing that I really liked about the class.

Beth and Amy, Global Change students, also discussed the importance of looking at global change issues from a variety of sources. Beth, for instance, noted how the media often paints an inaccurate picture of the global change landscape by portraying certain environmental effects as either uniformly positive or uniformly negative. She explained that a more critical analysis of environmental “inter-relationships” often produces an interpretation that is not so clear cut.

**Beth:** You read in the mass media that carbon dioxide levels are going to double and that there's a big hole in the ozone and there's going to be so much radiation. [The class] showed that, yes, the carbon dioxide levels might double, but there's a lot of other effects that are going to go along with it. For example, if there's more carbon dioxide, there's going to be more carbon dioxide for plants to use, which means that they'll be able to grow more, which means there'll be more plants. And that will affect the food chain, also.

So you saw that the views that you had been getting from just the media are really, really biased. If you really sit down and you look at how everything is connected to everything else, [you see] that there will be an effect and sometimes it'll be positive and sometimes things that we think are going to be the most negative might not turn out to be that negative at all. And everything just might end up working itself out just because of all the inter-relationships.

**Amy:** So you think for yourself a lot more through this course. You don't just hear something and assume that it's a fact. You hear something and say, “Why would they say that? What does that mean? Where did they get that information?” And then, “What about the other side?”

**Jean-Pierre (interviewer):** So it sounds like your thinking is more complex.
Amy: You do a lot more analyzing. I would say that I went into the course last semester with the idea that the world was doomed—that the ozone was going to disappear and we were all going to burn, or we were all going to suffocate on carbon dioxide. Well, maybe not that extreme, but I thought things were looking pretty hopeless. But the way that this course was approached—the fact that they started with how galaxies are created, how the universe was possibly created, how the earth has been changing since the beginning of time—gave me such a rounder view of everything and made me realize a couple of things. Yes, carbon dioxide is going to double within the next 50 years, and there's absolutely nothing we can do about it. There's nothing we can do to change it. Even if right now we cut emissions to the lowest we possibly could, it will still double within 50 years.

But the object now is not to just go around and say, “Okay, we're all going to die.” What we're working for now is not to cut carbon dioxide but to figure out how we are going to live with the higher levels; what will be the effects, both positive and negative?

And so, I gained a more realistic and more responsible understanding of what my role in the future is going to be. I feel like I can do something now. Not that I’m going to start recycling like crazy, like the organizations with those slogans, “Save the earth and save the whales and save the rainforests.” It's not that kind of an approach. It's a very responsible, systematic approach to what needs to be done.

And I would say that the coolest experience I had in this class, in terms of learning experience, was when we were discussing the effects of carbon dioxide on plant growth. Carbon dioxide makes plants grow more, but the plants, though larger, will still have the same amount of nutrients. Therefore, you have to eat more of the plant to get the same amount of energy. This has been shown in studies done on leafy green plants—just on the leaf, not on the roots—but not on root plants like turnips. So I asked, “What about the roots? Do they grow more and have less nutrients, too?” The reply was, “Well, no one’s studied that yet.” And I said, “Well, that’s what I want to do.” And [my instructor] said, “That would be a great senior honors project.” That was the coolest experience—to see that I could take all this information I'd been getting and take it a step further, to where it hadn’t been taken before.

Jean-Pierre (interviewer): That definitely classifies as a real learning experience.

Amy: That was the coolest thing, and that made me want to minor in Global Change. Because it deals with issues that affect everyone. There is no one in the world who will go unaffected by global change. So there's nothing that I could do that would help more people—if that's my goal—or that would affect more people, than to do something working in global change. After I get my degree, I plan to go on for a graduate degree in the School of Natural Resources. I just thought, “That is exactly what I want to do. That makes so much sense and that's something I could contribute that hasn't been contributed.” So that's my real learning experience.
Discussion B. Faculty views on computer-dependent learning activities

As mentioned earlier, the instructors indicated that the advantages of using computers in any particular learning activity are threefold. Tim Killeen, professor of Atmospheric, Oceanic, and Space Sciences, used an activity where he asked students to measure the ozone column abundance of a particular region and relate those measurements to the meteorology of that region. He and his colleagues believe that by using technology to collect and analyze data students will: a) develop a better understanding of how these two things (regional ozone abundance and meteorology) are related because they will have investigated the relationship in a hands-on fashion, b) not be distracted from gaining this meaningful understanding by digressional calculations and graphing, and c) gain first-hand knowledge of the tools used to achieve this understanding. He also believes in the power of real world data and explained how real-time data sets from the United States Geological Survey provide the data for the models that students are constructing in class.

**Tim:** We study the Great Lakes and get real-time data sets from the USGS sensors measuring the water flows down the tributaries, the pH and the sediment loading. We put that into a model and build a real-time interface, so students can then come in for their term projects and say, “Now I'm in this Collaboratory space [a user-driven web environment that offers interactive access to global or regional datasets], in Houston, Texas, with all of these data sources. I can either do an experiment in one of these rooms where I'm measuring, say, an ozone column abundance, and relating it to meteorology of the region, or I can use the Collaboratory as a tool to get access to these multiple data sources, and the expertise that's in the Collaboratory.”

These same kinds of models can be run using real-time, real-world data from the fields of space and upper atmospheric science, according to Luis, a graduate student who develops the course website.

**Luis:** We're looking at space science or upper atmospheric topics. We take data sets that are available there, simplify them somewhat, and build a lab around them. So we try to give sort of real-world examples about what scientists are concerned with at this current time, and then let the students investigate it themselves.

Below, a central administrator expands further on the value of using real world data. He says that the use of the Web in the Global Change course is not just a way of delivering information. It also trains students how to use tools that allow them to manage an “information explosion.” This training is crucial to their future capacity to understand the science and public policies that affect the environment, according to him.

**Central administrator:** The success of the course hinges on its ability to provide students with an enormous range of primary sources and fresh research about global change, about the climate, global warming, about the efforts to measure environmental change. It also gives them the ability to sort through that research and these sources in an effective way, so that the students can take that information and turn it to their own learning purposes. It's a place where they're managing vast amounts of data and making it transparently accessible so the
students can use it to do stuff they want to do inside the class. There are, of course, many other kinds of teaching that don't need the type of information that the Internet provides. You may have the seminar or books. But the Global Change course, I think, shows how the ability to manage an explosion of information [through the ability to manage on-line information] is crucial to certain courses in science and public policy.

Dan Mazmanian, Dean of the School of Natural Resources and the Environment, reiterated that students can use technology for their own learning purposes. He believes the Internet is the tool providing them “ready access to all the other information” they need to “pursue a line of inquiry” independently.

Dan Mazmanian: Through the use of technology, the web searches, and the links, they have ready access to all the other information. It's kind of like the unfolding of a book or a story, which is the way a CD-ROM or website should be used. So the students can actually pursue that line of inquiry pretty rapidly.

Susan (interviewer): It's like giving them a tool box.

Dan Mazmanian: It is. It is exactly that.

Discussion C. Student views on computer-dependent learning activities

As Tim Killeen pointed out earlier, “our evolving understanding of the human relationship with the earth system [involves] a lot of complexity, a lot of issues.” Students told us that they are able to learn about such issues through lecture, web-based literature, and handouts, but that they are better able to understand intricate systems like the carbon cycle and other chemical systems through computer models that: help them visualize concepts, give them hands-on tinkering experience, provide real-world examples, and help them develop skills for managing complex information.

Getting students to see a process was one of the issues the U of M bricoleurs brought up when discussing (in the Goals section) the importance of allowing students to “tinker with the idea they've been given.” This tinkering, according to the instructors, allows students to “come to conclusions on their own,” which cannot be done as effectively when students have only static information from which to make conclusions. One student noted that she would not have understood certain concepts “anywhere near as in-depth” were it not for the hands-on exploration that she was able to do with the modeling software used in the Global Change course.

Sally: I have such a better understanding of the material after having the labs. There's no way I could have gotten that without the whole modeling thing. And I would have understood it, but not as in-depth, not anywhere near as in-depth.

Laura, another student who took the course in a previous semester, emphasized that “constructing, playing with, and manipulating a model” enhanced her learning much more than just memorizing the results of such a model.
Laura: The professors do show those kinds of things, but it's a lot more interactive for students to put a graph together themselves. I think that learning is enhanced by a student taking raw data and making a graph rather than just looking at the finished product. It'll mean less to them and they won't retain it, I think. And I can tell you that because of my own experiences. I knew a lot more about the carbon cycle after constructing a model, playing with it, and manipulating it than I ever did by memorizing the relationships.

Students also reported that manipulating the figures on a modeling program is instructive, because “tweaking the numbers” in one area affects everything else in the model. They said that seeing such models on paper would detract from their ability to envision such dynamic global interactions because they would only be involved in seeing results, as opposed to putting the models together on their own.

Ruth: If you're just in a science-based major and you don't like the way the results come out, you can tweak the numbers so that you get the right answer. But if you're using something like a modeling program and you tweak that number, you’ll get the right number, but it still affects how everything else is viewed as well.

Beth: I think a lot of our assignments could have been done on paper—I just don't think it would have been as effective. When we did the STELLA models, we actually put them together. Our GSI [graduate student instructor] would show us how, but we actually did it. We actually would connect things to what our GSI would ask us. If we would have done that on paper, it wouldn't have been us doing it. It would have been the professor.

Amy: It's not just drawing the picture, you run it, too. You run the model.

Beth: And you make graphs.

According to Amy, independent investigation of real-world science and social issues allows students to contextualize facts and figures related to those issues. She explained, for example, that the deleterious effects of a “population boom” can only be determined upon considering the social background of the area in which such a boom occurs. ArcView allowed her to create such a real world background in a way that she “just doesn't get from somebody telling [her].”

Jean-Pierre (interviewer): How does ArcView go beyond the numbers? Can you express that?

Amy: We watched a movie in our first lab about a naturalist, Paul Ehrlich, who collects butterflies. But what he really did was make these big, doomsday predictions about the end of the world. He goes to Bihar, which is, I think, the poorest state in India, and he sees a lot of babies being born, and he comes back and says there's this population boom in India and nothing can be done, and it's the end of the world. But he doesn't understand that this is not a population boom, and that they always have that many children, and that a lot of those children will die. It's an agricultural state, so they need a lot of children because they work on the land. So then he gives all of these numbers and says that by the year 2050, India's
population will grow by five times or something. I don't know the numbers. And that doesn't mean anything to me because I see him as coming from absolutely no background. The population has doubled before, we were worried, and now we have six billion and we're still doing okay. So what if we have another six billion? Maybe we'll still be okay. We really can't know.

But if I can take something like ArcView and look at the way population is dispersed, like if you tell me that there are a lot of people in New York City or in the State of New York, vs. telling me there are a lot of people, with their tradition, in India, that means a big difference. Because New York has complex sewage systems. So that means a lot to me. And ArcView takes those populations, and will split it up, and you can see how different population growth occurs in different parts of the country. It just adds another aspect to that that I just don't get from somebody telling me the population doubles. It gives you a complete picture. Instead of them just saying something that you take for truth automatically, it lets you formulate your own view, which might be a little more cynical, but is also more complete. And it gives you the ability to analyze as well, not to just repeat.

The Internet provides access to real-world data sets, acts as a tremendous resource for literature on global change issues, and simultaneously gives students on-line information gathering experience. Using the information from this interactive resource, Global Change students create their own website. This work both exposes them to global change issues and teaches them to critically examine the contents of websites that can be created and maintained by anyone.

**Sam:** We made our own website to show us how easy it is so that you become a bit more skeptical of websites you read. They are very subjective. We also did some research on the Web for various things.

**Julia:** This year, it’s required that every student make a website by the end of the course. Students pair up in groups of two or three and do a significant amount of research on a topic that was covered at some part of the course. Then they do a quick presentation to show their website and explain what they did. And I thought that was really useful because it was the first time I had done a significant web development project.

**Discussion D. Faculty and student views of the role of lecture**

The lecture portion of the Global Change course in some ways resembles the standard university lecture format. Students listen and take notes while a professor talks about a certain subject. However, during our interviews at the U of M, some of the faculty signaled a desire to modify this format by making lecture a place where more student dialogue could occur. The students from the course said that this modification was already in motion. They told us that to succeed in the course, they needed to be active during lecture sessions. George Kling, professor of Biology, presented this point when discussing ideas for restructuring the lecture design.

**George:** I go to the class with fifty to seventy minutes of material to deliver and always try to use every minute. I like to stop and ask for questions and promote dialogue. I'm thinking this semester of some ways that I can do things differently that might allow more time for
dialogue. You have to build it into a more discursive type of framework. I don't think dialogue happens easily or naturally.

According to Luis Fernandez, a graduate student assistant, Dave Allan is a traditional lecturer who focuses less on audio-visual tools, videos, and animation than on being a “dynamic speaker,” drawing on his own research and giving students “extra information that they can't find in the [web-based] notes as an incentive to show up to class.”

**Luis:** Dave Allan uses a lot of case studies that he draws from his own research or that he finds on the Web before class. He'll bring up a case study, website, or an article in class to illustrate the traditional material that the students can find on the course website. He told me a couple times that he likes to give students extra information that they can’t find in the notes as an incentive to show up to class.

Dave himself said that, despite the Web’s role as a “terrific enabler of self-instruction,” instructors should not “lose sight of how they communicate.” To illustrate this point, he described a lecture that Professor Gayl Ness, sociology professor, gave that kept him on the “edge of his seat.” The material that Ness covered in that lecture would not have been nearly as powerful if Dave had just read about it on the Web.

**Dave:** The Web is such a terrific enabler of self-instruction. You can go out there and get all this information and bring it back and integrate it. And I am not personally attached to the Web as the delivery system for lecture material. For instance, Gayl Ness, [emeritus sociology professor] gave this fantastic lecture a while ago. I was just on the edge of my seat through that whole thing. He is still, I am sure, the absolute top person in his field. He has a tremendous amount of field experience and can talk about his experience in Thailand and Southeast Asia. He's seen these changes first-hand, and has, I think, a masterful integration of the topography and the social processes that are interacting and both drive it and result from it. I thought he was just a marvelous speaker. He spoke with passion and humor. If you were to say, “Let's put somebody up here who gives a heck of a good lecture, let's not worry about whether they are using computers or technology, they just give a heck of a good lecture,” I would say it would be hard pressed to top that one. He used transparencies and he talked. The most powerful part about it was Ness, as a lecturer, not whether it was already packaged on the Web or whether you put a glitzy Power Point presentation together. And that is that personal sense to communication [that we should] not lose sight of.

Some of the students we spoke with corroborated Dave’s point, with respect to a particular type of lecture style. They pointed out that “how [instructors] communicate” and how students respond are equally important because they have a complementary effect on one another. Students must take a dynamic role that goes beyond just “taking the lecture notes that are already printed out and not adding anything to them” and instead need to actively “ask why.” Beth, meanwhile, pointed out that Professor Kling, professor of Biology, inspires this kind of inquiry by asking questions with deceptively simple answers, thereby dissuading students from relying solely on their intuition, and forcing them to rely instead on careful thought and analysis.
Amy: Don’t come into the course thinking, “Just sit and absorb,” and “This is an easy course.” Don’t just take the lecture notes that are already printed out and not add anything to them. Add things and look for things that you’re interested in and question everything. Always ask why—they give you a statistic, ask where that came from—don’t just take anything [at face value]. Because a couple times, especially with Professor Kling, he would tell [us] something and everyone would say okay [without questioning], and then he’d say “No!”

Beth: He says, “Ask why. Don’t you even wonder?”

Amy: He’ll say, “You just believe that!”

Discussion E. Faculty views on the role of personal qualities in fielding an interdisciplinary course

In discussing the personal resources necessary for developing and maintaining an initiative like the Global Change Project, the faculty emphasized three qualities:

- a willingness to put forth an “uphill effort,” by working through the inevitable obstacles that surface during the implementation of interdisciplinary curricula.
- leadership
- a “bottom-up,” “grassroots” mentality that instructors, not administrators, are responsible for the success of the initiative.

They observed that if these characteristics were absent from the people involved in creating and maintaining the project, it would “fall through the cracks,” especially in a decentralized university like the U of M. George Kling, biology professor, and Bob Owen, associate dean of the College of Literature Sciences and Arts, emphasized the importance of a committed faculty.

George: I think we have a group of people who are really excited about doing this and willing to do extra work to be involved in it. It almost fell apart, sometime around ’94-’95 when Gayl Ness retired. But Tim Killeen picked it up, he salvaged it, and despite all the support for interdisciplinary education, all the recognition we’ve got, this is still mostly an uphill effort. We are still rolling a rock uphill to make a course like this continue.

Bob: I think if you’re committed, remain committed. Don’t pull out halfway. As you reach bumps in the road, you’ve got to keep going. You don’t dip your toe in the water for something like this. You’ve got to have a total commitment.

Dan Mazmanian, dean of the School of Natural Resources and Environment, added to George and Bob’s points about commitment by praising the group’s resilience, their ability to maintain the course despite not having an “established niche” in the University.

Susan (interviewer): You mentioned something earlier that I thought was pretty significant about how this course or this emerging minor has no natural niche. Typically, groups that have no natural niche also fall through the cracks in terms of reward structure things.

Dan: I think that this group has lasted longer than most, for those very reasons.

Susan: For which reasons?
Dan: That, without having an established niche and organizational place and all those things that go with it, they typically do kind of fade into the woodwork. The work they’re doing is above and beyond the call of duty. It's not in any of their job descriptions. They've held together as a critical group for six or seven years. They have stayed with this despite the fact that it hasn't had a natural niche in any department. They stayed with this despite the fact that they had to reach across the different colleges and schools at the University of Michigan to make this happen. They have been a very thoughtful, integrated group working together as a real team. And it's on the surviving end, which is a compliment to them. Organizationally they should have fallen through the cracks a long time ago, but they haven't because they have resilience.

Tim Killeen, professor of Atmospheric, Oceanic and Space Sciences, commented further on his own resilience in the face of organizational obstacles saying that, in order for the course to work, the faculty need to remain committed and continue to improve the course.

Tim: I decided that if we were really going to make this work, we had to keep at it. That's the way I feel, and that's the way other people in the group feel. Keep working on course development—learning how to do it better and better, and modifying it, and adjusting it, and evaluating it. And over the years, this effort has been validated. [We didn’t expect it would be] like that at the beginning. We all thought that we could just do this, show up and plot our graph packets, and lo and behold, interdisciplinary course—here it is.

Intimately connected with the faculty’s ability to “keep at it” is their recognition that they are part of a “bottom-up effort” in which no single department takes responsibility. Below, Bob Owen stressed the value of taking ownership in an independent course like Global Change.

Bob: Some of the same things that help us tend to get in our way. We are well-known as being an extremely decentralized university. Which means that on a relative scale, individual departments, individual faculty, tend to be far more independent. That independence gives them the freedom to explore and talk about things they want to do. At the same time, that independence also means that you can't really send down an edict from an on-high administration and say, “Do this.” They'll just say, “No, we're not going to do this.” So, that's why it has to be a bottom-up effort to do this. At a place like Michigan, you need to send a green light to the faculty saying, “This is a goal.” You then provide the means and incentive for them to get there. They need to gain ownership, otherwise it won't happen.

I've heard and seen the applause of the provost and everybody around the University. They all applaud the initiative, but it only worked, and works, because it is driven from the bottom up, from the individuals who are willing to go the extra mile. I do not see an easy change whereby this process can come from the top down. Now, a course like this is what the University wants to do, but as I see it, as soon as it's not driven by [faculty] individuals, things don't work.

Bob’s emphasis on the responsibility of “subunits” (the Global Change faculty) to independently affect change is reminiscent of what Karl Weick (1976) called “loosely coupled organizations,” a term that was applied to colleges and universities by Birnbaum (1988).
Discussion F. Faculty views on the extra time needed for, and the special importance of, the GSI role

U of M professors discussed the challenge of coordinating individual Global Change lectures into a coherent, chronologically organized course. George Kling, biology professor in the College of Literature, Science and Arts, emphasized the extra time professors need to team teach.

George: *There is an inherent inefficiency in team teaching that is not expressed when you’re teaching a course alone. When Ben [van der Pluijm, Geology Professor] thinks about his lecture, he says, “Well, I’ll talk about this, and then I’ll talk about that.” He has a logical progression in his mind. But sometimes we have to say, “No, you’re not. You can’t have oxygen in the atmosphere until we’ve evolved life. And that doesn’t happen until this time, so you have to change the way you are presenting this so that it fits with our overall scheme through the entire semester.” We’re all very efficient at thinking about our discipline, but this is interdisciplinary. So all of a sudden, we have to fit what we know in with these other disciplines. And we don’t know them very well, so these other people are telling us, “No, you can’t do that Ben. The world doesn’t really work that way. That’s the way you think geology works, but in the big picture, it doesn’t.” So that takes a tremendous amount of extra time on top of what we give a normal course that we teach by ourselves.*

Expanding on George’s point, Tim Killeen, professor of Atmospheric, Oceanic and Space Sciences, gave an example of a topic that was mistakenly presented four different times by four different professors.

Tim: *The problem with interdisciplinary team teaching is all the disconnects. For example, we taught the peppered moth four times in one semester. The peppered moth is an example of rapid evolution in an organism in response to external change, which in this case was a rise in pollution in England during the Industrial Revolution. It was taught four times by different professors. There wasn’t enough coordination.*

George Kling and Ben van der Pluijm, geology professor, stated that to appropriately coordinate the lectures, the instructors themselves need to become students of each others’ discipline.

George: *To properly organize the classes, you have to process something you don’t really know that much about. You become a student who has to learn material from your colleagues’ fields. You are a freshman. All of a sudden I have to figure out how Ben puts his stuff together. Just like the students are figuring out how everyone puts their stuff together. We’re all students of the others’ discipline. That is why we all teach this instead of one person.*

Ben: *Exactly, that’s why this matter of preparation time comes in again, because all of a sudden I have to speak about prokaryotes and eukaryotes. I just mentioned something in class because it was not really important from the rock perspective. I see now how it could be made a lot more important after having talked with my colleagues, which forces you to change, even though what you have said is still perfectly valid in your own field.*
The GSIs have a similar time burden when it comes to connecting information from one field to another. Although they do not have to coordinate lectures like the professors, they are responsible for helping students synthesize the diverse content of the course. This means answering questions about subjects that are unrelated to their own studies.

**Ben van der Pluijm,** geology professor: *In order to answer students’ questions in lab, the GSIs need to know what so-and-so said and what was meant. Well, that requires the GSIs to do a lot more than they would normally do as GSIs. So that structure can’t stay. You can’t expect every GSI to know economic models as well as social models, psychological, geological, and biological. So in the short run, it’s a difficult experience for them, because sometimes they work 30 hours in a week. This is just another reason why there aren’t very many courses like this, that have a true interdisciplinarity to them. And there won’t be in the current structure. Ten years from now, I could see us sitting around the table and having exactly the same conversation, asking the same questions.*

***

**George Kling:** The GSIs probably work more than they are supposed to. There are pretty strict contracts now, 17 to 20 hours a week, that a full-time position is supposed to work and they are working 25 to 30. We drop a lot of responsibility on them and it is pretty clear that if they don’t live up to it, we are in big trouble.

Dave Halsing and Patrick Livingood, GSIs, presented their own views on the time burden of repairing the interdisciplinary disconnects, explaining that their willingness to do so is linked to their dedication and love of teaching. They contend that, without these characteristics, GSIs might not be as keen on taking extra responsibility.

**Dave:** In a large class with lots of professors like this, the professors aren’t there every day in lecture. And so we’re kind of the source of continuity for the students throughout the semester...And I think that they’re very lucky. I mean, that’s going to sound like I’m patting ourselves on the back, but I think they got lucky that they got a batch of GSIs last semester and this time who enjoy teaching and are dedicated. I got a lot of feedback from students saying that the discussions where we synthesized the lecture topics were very helpful.

*I know a lot of graduate students are GSIs because of the tuition credit and the salary. They don’t particularly love it, and it’s a “have to” rather than a “get to” for them. And if one of those people wound up in a course like this, I think the course would suffer a lot. Where they do better is in courses where the instructor takes a larger role, and the GSI is really for support and grading and things like that.*

**Patrick:** The students come in and get the lecture from the professors but we run all of the other actual student activities or interactions.

**Dave:** Half-way through, as Patrick says, we sort of figured out, “Hey, if this semester is going to work, it’s going to work because we’re going to take care of these things.” And so we did. But I think there needs to be one person, one faculty member, who takes responsibility
for the course from beginning to end and works with the GSIs to keep everything running smoothly…Because there’s so many different faculty drifting in and out, there isn’t one person running the content or the flow of the course. There’s no one person that the students can go to.

Discussion G. Faculty views on the U of M reward structure

As we stated elsewhere, the U of M rewards structure presents a challenge to the faculty in their attempt to implement the Global Change course. The *bricoleurs* told us, for instance, that junior faculty members were wary of participating in the course because of the potential damage such participation could cause to their tenure prospects. One professor said that it is difficult to convince the high-level administrators to give professors the amount of credit they deserve for teaching in Global Change. He argued that, because of the time and workload burdens that teaching in Global Change brings with it, a professor who teaches a fraction of the Global Change course should receive greater credit than for teaching a disciplinary course. However, when he and his colleagues try to recruit professors from different departments to teach in Global Change, the chairs of those departments say, “[the reward structure] doesn't work that way.” In fact, some professors who teach in Global Change get no credit at all for doing so, but rather participate voluntarily. This voluntary participation can potentially cut into the time they spend on research, which, especially for junior faculty on a tenure track, is risky.

**Dan Mazmanian:** Global Change is not an enterprise that has attracted many junior faculty because their colleagues have told them that inter-discipline has all those wonderful virtues, but given its tenuous political organizational footing, you probably ought not spend a lot of time with it right now. That’s probably safe advice coming from your peers. I don’t say that. I don't treat it differently than other kinds of activities.

Bob Owen, associate dean of LS&A, stated that he would give junior faculty members that same advice if he were in a position to do so.

**Bob:** If I put myself in the role of a department chair, I would probably counsel an assistant professor to hold off on their involvement until they got their own research effort going. After that hurdle I think that faculty can be more free to get involved in projects of this sort. The bias certainly would be toward tenured and full professors.

Tim Killeen, professor of Atmospheric, Oceanic and Space Sciences, expanded on Bob's point, using a junior faculty colleague of his as an example.

**Tim:** Lisa Curran [SNRE] is very dynamic, passionate, and valuable for the classroom element, particularly for something like global environmental change. So we want to bring her in, but we don't want to damage her prospects for tenure track.

Below, Lisa Curran, a junior faculty member herself, questioned how changes might be made so that the reward structure recognizes teaching efforts in team settings like the Global Change course.
Lisa: If you teach your regular load and you team-teach on the side, team-teaching counts for less, and I think people want to see that change. The question is, how do we implement it?

Ben van der Pluijm, geology professor, said there needs to be a change not only in the way teaching time factors into tenure considerations, but also in the way that preparation time is calculated. According to him, “prep” time is especially important in the Global Change course because it requires multiple professors to synchronize their lectures.

Ben: Dealing with the large amount of prep time to teach this kind of course is the major problem that you run into with interdisciplinarity. That is why we need to talk about it. The current organizational structure does not have that solution built in, because it still counts your hours in the class as your teaching load. In other courses you can wing a class but you can’t here because if I am not done, George will simply say, “Friday is my turn, so if you didn’t get to formation of oxygen in the atmosphere that ruins my class.” So, it’s very different and that is what people don’t realize until you’ve done it and the administration has heard enough about it. It is a fundamental structural change that the university will have to make, but that’s got to be very expensive. We are talking about a fundamental change of how we see and how we spend our time.

George: I put in about ten hours a week, which is 25% of my work time, but I don’t give any lectures, and as Ben said, if other people haven’t had the experience, I really don’t think they appreciate it. They just think you are making it up.

According to Lisa Curran, the types of challenges George talked about are due to the type of pressures that characterize research universities. Despite this, however, she observed that her colleagues are taking steps to change the way administrators value teaching.

Lisa: Let’s face it, in the end, this is a research institution. And so one of the difficulties if you enjoy teaching—and I actually love it—is how will the standards reflect that? I think the provost, Tim Killeen certainly, and a number of people are trying to change how much teaching is worth in a tenure process versus just counting publications, per se. And Nancy Cantor [provost] has been pressuring deans and chairs...The questions that abound are: How do we make the review process more equitable for this teaching service? And how do we then find people that want to do this—and there are many senior people who don't want to. One common theme is, “Oh, we've got to keep junior faculty out of this, because it's just too much work, and there are no rewards.” Well that seems like a very defeatist attitude to me. I think that external reviews need to have recognition for these things, like having a website win an award. This could mean that an organization like NSF says that a review process must look at the impact of this work.

In order to change the value of teaching, teaching time must be fully calculated. As Lisa Curran said above, team teaching across departments does not get counted equally with teaching that goes on in a single department. Bob Owen suggested that courses be cross-listed to solve this problem.
Bob: One way to get around the problem of having professors teaching across departments, in terms of who gets credit, is to have courses cross-listed. So, there's been an effort to do that with what we call “university courses.”

Another way to increase the value of teaching at the University is by creating professorships that reward quality teachers, according to a central administrator.

Central administrator: In the early ‘90s the university created professorships that recognize excellence in teaching. There are ten or twelve of these very distinguished professorships that provide rewards and prestige for faculty. Many steps have been taken at the department and college level which have produced a real turn-around.

Dan Mazmanian, dean of the School of Natural Resources and Environment, said that, although he is not in a position to hand out rewards for good teaching, he does make sure that no one is penalized for teaching outside of his or her department.

Dan: I surely don't penalize participation in Global Change, but I'm also not on the promotion and tenure committee other faculty members are. So they have a reality to live with, which is a peer-based reality. I can do a lot, but when it comes time for a tenure decision, I can't walk in and say, because junior faculty member x spent a long time with Global Change, we're going to overlook, or treat him or her differently than others in terms of their research, in terms of their service to the school, and so on and so forth.

Susan (interviewer): Have you seen any situations where faculty who have been involved in this course, either at the core, or in a more peripheral way, have been penalized, from the standpoint of tenure and reward?

Dan: Not in SNRE. Not in my school.

George Kling, biology professor explained that the tenure and reward structures at state schools should more closely resemble those of private universities where professors have more time to try innovative teaching methods.

George: Now, private universities have a lot more money to invest in reducing the overall time commitments of professors. That allows them to teach in this new kind of way. Columbia has twice as many Graduate Student Instructors as they do faculty, whereas we have about one-fifth. We have many more faculty than graduate student instructors. So they have a huge amount of money and resources to spend that we don't have. Stanford, Harvard—the same way. I don't know how that is going to work with state schools. That is why I think it has to be a very large systemic change that involves society.
Resource A. Institutional Context

[All of this information is taken from the UMICH website http://www.umich.edu/~info/aboutum.html]

The University of Michigan (U of M) was founded in 1817 as one of the first public universities in the nation. The school moved from Detroit to Ann Arbor in 1837, when Ann Arbor was only 13 years old.

Today, U of M is one of only two public institutions consistently ranked in the nation's top ten universities, with over 51,000 students and 5,600 faculty at three campuses. Over 5,500 undergraduate courses are taught each term in over 100 programs. Undergraduate, graduate and professional students have a choice of 17 separate schools and colleges, 588 majors, over 600 student organizations.

The students at the University of Michigan come from all 50 states and over 100 foreign countries from Afghanistan to Zimbabwe. Almost 50% come from the top five percent of their graduating high school class and 66% are in the top tenth of their class.

Michigan's teaching and research staff include an astronaut, distinguished world authorities, Pulitzer Prize winners, internationally acclaimed performing artists and composers, Supreme Court Justices, best-selling novelists, artists, and filmmakers. Michigan has more than 100 named endowed chairs.

Michigan receives over $374 million in research expenditures annually, the largest research expenditure for any university in the country. The diversity of the University's research activities, from medical to social to cultural, is a major contributor of Michigan's capacity for growth and development.

Resource B. Methods Used to Produce this Case Study

Susan Millar and Jean-Pierre Bayard, researchers for the Institute on Learning Technology, conducted interviews and observed labs and classrooms during mid-January 2000 at the University of Michigan. We interviewed:

- four “core” Global Change faculty members:
  - Timothy Killeen, at the time, director of the Space Physics Research Laboratory, professor in the Atmospheric, Oceanic, and Space Sciences Department of the College of Engineering, and director of the Global Change Project, and as of fall 2000, director of the National Center for Atmospheric Research
  - Ben van der Pluijm, professor of Geology and present director of the Global Change Program
  - David Allan, professor, School of Natural Resources and Environment
  - George Kling, professor of Biology, School of Literature Sciences and Arts
- one new Global Change faculty, Lisa Curran, assistant professor, School of Natural Resources & Environment
three graduate teaching assistants
- David Halsing, currently completing a Master of Science degree in Resource Policy and Management
- Patrick Livingood, graduate student instructor, Ph.D. student, School of Natural Resources and Environment
- Luis Fernandez

Professor Daniel Mazmanian, then dean of School of Natural Resources & Environment and as of fall 2000, C. Erwin and Ione L. Piper Dean and professor of the University of Southern California’s new School of Policy, Planning, and Development

Robert M. Owen, associate dean of Undergraduate Education of the College of Literature, Science and the Arts, and professor of Marine Geochemistry

two leaders from the central administration

Two evaluators
- Eric Dey, professor in the School of Education and member of the U of M Center for the Study of Higher and Postsecondary Education (CSHPE)
- Anne Chapple, graduate student, CSHPE, School of Education, and faculty in the Department of Law, History & Communication

eight students
- seven Global Change students
- on Global Change I student alumna who now serves as an administrative assistant for the course.

In addition, we observed one of the weekly organizational meetings in which the Global Change instructors participate, two of the weekly Global Change lab meetings, and one of the large lectures (given by Gayle Ness, professor emeritus of Sociology, and former member of the core Global Change faculty group).

At the time of our visit, these Global Change faculty and teaching assistants were in their third week of classes with a group of approximately 190 students enrolled in Global Change I.

The interviews were guided by the protocols used in all the Learning Through Technology case studies and were taped and transcribed. Andrew Beversdorf analyzed the interview material, and with help from Susan Millar, as well as from Sharon Schlegel and Mark Connolly, produced this case study.

Acknowledgements:
The authors thank the University of Michigan faculty, staff, and students who participated in this study. These individuals very graciously responded to our request for their time and attention. In particular, the authors thank Professor Ben van der Pluijm for the many hours and the thoughtful attention he dedicated to the improvement of this document.

This case study is based on a deeply collaborative analysis and planning process undertaken by the NISE’s Learning Through Technology “Fellows” group: Jean-Pierre Bayard, Stephen Erhmann, John Jungck, Flora McMartin, Susan Millar, Marco Molinaro.
The Fellows, in turn, benefited substantially from members of the College Level One Team: Susan Daffinrud, Art Ellis, Kate Loftus-Fahl, Anthony Jacob, and Robert Mathieu.

**Resource C. Types of Course Evaluation Data Collected**

- **Surveys.** During each semester that Global Change I was offered from fall 1997 through spring 2000, the evaluation team administered web-based baseline, midterm, and final assessment surveys, and then analyzed the resulting data and presented their findings to the faculty group at each semester's end. These surveys use both closed- and open-ended questions to gather information about students' experiences with the labs, lectures, and Global Change website. During the 2000-2001 academic year, only baseline and final surveys were administered, and the evaluation team analyzed the resulting data and presented reports to the faculty group within several weeks after the end of each term. As of fall term, 2001, the Global Change teaching staff will transition to administering simplified baseline and end-of-term web surveys only, which the teaching staff will analyze themselves. For more detail on Dey’s survey-based findings, see below.

- **Interviews.** During the early years of the UCDT project, interviews were conducted with the faculty, teaching assistants, and administrators to understand their experiences with the UCDT program, focusing issues pertaining to interdisciplinary teaching at the University of Michigan.

- **Observations.** A member of the evaluation team attended most of the lectures and some of the labs during a substantial portion of the fall 1997 semester. Conducting observations is standard procedure for new evaluators who join the Global Change project from time to time.

- **Focus Groups.** The evaluation team conducted a student focus group during the 1997 winter semester to gather the collective experiences of students.

- **Classroom Assessment Techniques.** On the urging of the evaluators, the faculty experimented with the following two easy-to-use “classroom assessment techniques,” the One-Minute Paper, and a web-based forum for weekly commentary on lectures and labs known as “GC Week,” both of which are designed to assess course-related knowledge and skills and assess learner reactions to lecture and laboratory instruction.
  - In previous years (though not during the 2000-2001 academic year), the faculty employed One-Minute Paper exercises to assess the results of the weekly labs. (To use the One-Minute Paper, an instructor stops class two or three minutes early and asks students to respond briefly to some variation on the following two questions: “What was the most important thing you learned during this class?” and “What important question remains unanswered?”) When we conducted interviews for this case study in January 2000, the

---

*These data were collected by an evaluation team led by Professor Eric Dey (Higher Education, University of Michigan) as part of the School of Education’s Undergraduate Curriculum Development Testbed (UCDT) [http://www-personal.umich.edu/~dey/ucdt/index.html].*
students were writing One-Minute Papers (for which they received a small number of points), and submitting them to the evaluators, who then noted which students submitted responses, stripped the students’ names from the data, collated the data and provided it to each GSI.
- In order to minimize the amount of class and lab time used for assessment activities, as well as routinize and make the data acquisition process more efficient, the “GC Week” initiative was implemented during the fall 2000 academic term and was operational through winter term, 2001. Students were required to access a web-based evaluation form and to rate numerically—on a scale from 1 (very inefficient) to 5 (very efficient)—each of three weekly lectures and one weekly lab for effectiveness of the lecturer/GSI as well as effectiveness of the lecture/lab content. Students were also given the opportunity to submit comments on how the lecturer/GSI or lecture/lab material could be improved. For this work, students were also awarded a small number of points.

**Resource D. Results of End-of-Semester Survey**

Below are data from the end-of-semester survey administered to Global Change I students in fall 1999.

**I. Lab Experience**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The lab assignments seem carefully chosen.</td>
<td>12.3%</td>
<td>67.7%</td>
<td>10.8%</td>
<td>4.6%</td>
<td>4.6%</td>
</tr>
<tr>
<td>2. The lab assignments are intellectually challenging.</td>
<td>7.7%</td>
<td>72.3%</td>
<td>12.3%</td>
<td>3.1%</td>
<td>4.6%</td>
</tr>
<tr>
<td>3. Laboratory assignments make an important contribution to my understanding of the topics discussed in lecture.</td>
<td>7.7%</td>
<td>44.6%</td>
<td>32.3%</td>
<td>7.7%</td>
<td>7.7%</td>
</tr>
<tr>
<td>4. <strong>ArcView</strong> has helped me understand Global Change concepts and principles.</td>
<td>13.8%</td>
<td>56.9%</td>
<td>20.0%</td>
<td>4.6%</td>
<td>4.6%</td>
</tr>
<tr>
<td>5. I feel confident in my ability to use <strong>ArcView</strong> to construct models.</td>
<td>24.6%</td>
<td>67.7%</td>
<td>4.6%</td>
<td>3.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td>6. <strong>ArcView</strong> helps me understand the relationships among different variables.</td>
<td>18.5%</td>
<td>63.1%</td>
<td>10.8%</td>
<td>6.2%</td>
<td>1.5%</td>
</tr>
</tbody>
</table>

---

\[b\] These data were compiled by an evaluation team led by Professor Eric Dey (Higher Education, University of Michigan) as part of the School of Education’s Undergraduate Curriculum Development Testbed (UCDT) [http://www-personal.umich.edu/~dey/ucdt/index.html].
### II. Lecture Experience

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Having several instructors give the lecture contributes to my understanding of the concepts and principles related to Global Change II.</td>
<td>38.5%</td>
<td>46.2%</td>
<td>10.8%</td>
<td>3.1%</td>
<td>1.5%</td>
</tr>
<tr>
<td>2. The transition from one instructor to the next interferes with my ability to learn.</td>
<td>6.2%</td>
<td>7.7%</td>
<td>12.3%</td>
<td>66.2%</td>
<td>7.7%</td>
</tr>
<tr>
<td>3. I have learned a good deal of factual material in this course.</td>
<td>36.9%</td>
<td>56.9%</td>
<td>6.2%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>4. The knowledge I have gained through this course has improved my ability to participate in debates about global change.</td>
<td>30.8%</td>
<td>63.1%</td>
<td>6.2%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>5. This course has encouraged me to think critically about global change.</td>
<td>46.2%</td>
<td>50.8%</td>
<td>3.1%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>6. It is difficult for me to understand how topics covered in the lecture fit together.</td>
<td>3.1%</td>
<td>16.9%</td>
<td>7.7%</td>
<td>60.0%</td>
<td>12.3%</td>
</tr>
</tbody>
</table>

### III. Web Experience

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Using the web has made a significant contribution to my learning.</td>
<td>32.3%</td>
<td>50.8%</td>
<td>12.3%</td>
<td>4.6%</td>
<td>0.0%</td>
</tr>
<tr>
<td>2. The links from the Global Change website to other internet websites have provided me with helpful information.</td>
<td>15.4%</td>
<td>24.6%</td>
<td>50.8%</td>
<td>6.2%</td>
<td>3.1%</td>
</tr>
<tr>
<td>3. I feel confident in my ability to use the web to gather information about global change.</td>
<td>52.3%</td>
<td>41.5%</td>
<td>4.6%</td>
<td>1.5%</td>
<td>0.0%</td>
</tr>
<tr>
<td>4. I have used the web skills I have acquired in this course to complete academic work for other classes.</td>
<td>16.9%</td>
<td>43.1%</td>
<td>26.2%</td>
<td>12.3%</td>
<td>1.5%</td>
</tr>
<tr>
<td>5. I have utilized the web skills I have developed in this course to investigate areas that interest me.</td>
<td>21.5%</td>
<td>38.5%</td>
<td>29.2%</td>
<td>9.2%</td>
<td>1.5%</td>
</tr>
</tbody>
</table>
IV. Personal Growth

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I have deepened my interest in the subject matter of this course.</td>
<td>39.4%</td>
<td>51.5%</td>
<td>6.1%</td>
<td>1.5%</td>
<td>1.5%</td>
</tr>
<tr>
<td>2. I am enthusiastic about the course material.</td>
<td>31.8%</td>
<td>50.0%</td>
<td>15.2%</td>
<td>1.5%</td>
<td>1.5%</td>
</tr>
<tr>
<td>3. I feel like I make an important contribution to the learning of others in the course.</td>
<td>12.1%</td>
<td>36.4%</td>
<td>40.9%</td>
<td>9.1%</td>
<td>1.5%</td>
</tr>
<tr>
<td>4. I have had opportunities to help other students in the course learn about Global Change concepts and principles.</td>
<td>10.6%</td>
<td>42.4%</td>
<td>34.8%</td>
<td>7.6%</td>
<td>4.5%</td>
</tr>
<tr>
<td>5. I feel empowered to act on what I have learned.</td>
<td>22.7%</td>
<td>57.6%</td>
<td>16.7%</td>
<td>3.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Glossary: Special Terms Used in the LT2 website

**Assessment** – What do faculty who are experimenting with interactive learning strategies (see *constructivism*) mean by “assessment?” In the simplest terms, assessment is a process for gathering and using data about student learning and performance. The LT2 website distinguishes the following two types of assessment:

- **Formative assessments** – activities that simultaneously (1) provide instructors with feedback about how and what students are learning, which the instructors can then immediately use to adjust and improve their teaching efforts; and (2) foster student learning directly because the students are in the process of performing such activities. (For more information, see the FLAG website, which features classroom assessment techniques that have been shown to improve learning.)

- **Summative assessments** – formal examinations or tests, the results of which faculty use to demonstrate in a way that is definitive and visible to people outside the course the degree to which students have accomplished the course’s learning goals.

Tom Angelo (1995) defines assessment as an ongoing *process* aimed at understanding and improving student learning. It involves:

- making our expectations explicit and public;
- setting appropriate criteria and high standards for learning quality;
- systematically gathering, analyzing, and interpreting evidence to determine how well performance matches these expectations and standards; and
- using the resulting information to document, explain, and improve performance.

When it is embedded effectively within larger institutional systems, assessment can help us focus our collective attention, examine our assumptions, and create a shared academic culture dedicated to assuring and improving the quality of higher education.
**Bricoleur** – a French term for a person who is adept at finding, or simply recognizing in their environment, resources that can be used to build something she or he believes is important and then putting resources together in a combination to achieve her or his goals.

**Constructivism** – According to Schwandt, constructivism is a “philosophical perspective interested in the ways in which human beings individually and collectively interpret or construct the social and psychological world in specific linguistic, social, and historical contexts” (1997, p.19). During the last 20 or so years, cognitive psychologists (James Wertsch, Barbara Rogoff, and Jean Lave, among many others) have found that constructivist theories of how people construct meaning are closely aligned with their observations of how people learn: knowledge is mediated by social interactions and many other features of cultural environments.

**Learning activity** – As used in the LT² case studies, learning activity refers to specific pursuits that faculty expect students to undertake in order to learn. Thus, “Computer-enabled hands-on experimentation is a useful way to get students to take responsibility for their own learning” is a statement of belief that a particular learning activity (experimentation) helps realize a particular teaching principle.

**Learning environment** – According to Wilson, a learning environment is a place where learners may work together and support each other as they use a variety of tools and information resources in their pursuit of learning goals and problem-solving activities (1995). This definition of learning environments is informed by constructivist theories of learning.

**Microcomputer-Based Laboratories (MBL)** – A set of laboratories that involve the use of (1) electronic probes or other electronic input devices, such as video cameras, to gather data that students then feed into computers, which convert the data to digital format and which students analyze using graphical visualization software; and (2) a learning cycle process, which includes written prediction of the results of an experiment, small group discussions, observation of the physical event in real time with the MBL tools, and comparison of observations with predictions.

**Seven Principles for Good Practice in Undergraduate Education** – These principles, published in “Seven Principles for Good Practice in Undergraduate Education” by Zelda Gamson and Arthur Chickering, were synthesized from their research on undergraduate education (1991). According to their findings, good practice entails:

1. Encouraging student-faculty contact.
2. Encouraging cooperation among students.
3. Encouraging active learning.
5. Emphasizing time on task.
6. Communicating high expectations.
7. Respecting diverse talents and ways of learning.

**Teaching principles** – Teaching principles refer to a faculty member’s more general beliefs about, or philosophy of, learning. For example, the idea that “students should take responsibility for their own learning” is a teaching principle. It is general and informed by a theory of learning. It does not refer to something specific that one might actually do in a course.
References


