Report by the Joint Subcommissions on What We Teach and How We Teach

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Summary of Recommendations

Faculty and Graduate Students: Creating a new institutional environment for learning about the information revolution

PHYSICAL AND HUMAN INFRASTRUCTURE

1. The University should make it a priority to equip a much larger number of classrooms than at present with network access and a significant number of classrooms across the campus with multimedia access.

2. The University should invest significant incremental resources to ensure that technical help is available to maintain equipment in working order and that instructional help is available to work in a "side-by-side" model for faculty and graduate students seeking to use information technology in teaching.

3. All support staff should be competent with information technology in their areas of responsibility. New hires should be required to have this competency; staff in place should be required to upgrade their skills to competency. The University should provide the training programs that will enable this.

DISSEMINATION AND COORDINATION

4. The University should create structures in which faculty, along with student and staff collaborators, work together and share their discoveries and expertise about information technology and teaching.

SUPPORT STRUCTURES

5. The University should establish processes by which faculty apply for release time specifically in order to establish or improve the instructional technology component of a new or existing course or to participate in the curricular development of new minors or concentrations on some aspect of the information revolution.

6. Departmental, college, and school executive committees should accept innovative and effective teaching, pedagogical research, and research with instructional technologies as a positive aspect of a tenure or promotion file.

7. Issues of intellectual property with regard to courses delivered by faculty and distributed by means of information technology should be clarified in ways that respect the interests of the faculty and the University.

8. The University should make target-of-opportunity funds available to hire faculty whose area of scholarship is in the information revolution, broadly conceived. These faculty should be cross-appointed to at least two disciplines or programs. These appointments should be distributed across the University.

GRADUATE STUDENTS

9. Graduate students should be given numerous and wide-ranging opportunities to work with faculty in developing uses of information technology in courses and in developing courses/curricula about the information revolution.

10. A number of centralized information technology facilities, available to graduate students and particular to their needs, should be established. These facilities should be devoted to areas of scholarly expertise that students from a variety of disciplines can draw on (e.g., the current GIS facility, computational modeling, large-scale database analysis, etc.).

Undergraduate Students and Learning Outcomes: Creating a new institutional environment for learning about the information revolution

UNDERGRADUATE PROGRAMS

11. Every undergraduate program should ensure that the significance of information technology and the information revolution is adequately and appropriately reflected in the program's curriculum.

12. Schools and colleges should be encouraged to adopt an "information revolution across the curriculum" approach to the teaching of the information revolution and information technology.

Learning Outcomes: Understanding the information revolution and evaluating its "information"

13. Curricula at the University of Michigan should enable students to a) evaluate information and its reliability in a critical fashion; b) incorporate information into a field of knowledge so that it serves a specific purpose or intellectual goal; c) gain an understanding of the some of the cultural, economic, political, social, and psychological implications of the information revolution and to grasp the legal and ethical issues it raises.

FLUENCY AND CONCEPTUAL SKILLS

14. Schools and colleges should develop introductory information technology courses for credit that will realize the three learning outcomes outlined in recommendation 13. Sufficient sections should be made available to all students who wish to take them.

15. At the same time, the University should develop, perhaps through ITCS or CRLT or through college and school learning centers, a series of non-credit workshops for students that address these learning outcomes. These workshops might also be made available to faculty, staff, and graduate students.

MULTIMEDIA COMMUNICATION

16. The University should develop an interdisciplinary concentration or major in multimedia studies. Possible participants in the concentration might come from, but need not be limited to, the School of Information, the School of Art and Design, the School of Music, and departments such as Electrical Engineering and Computer Science, Film and Video, Communications, and English.

17. The concentration or major should include a series of two or three well-publicized introductory or sophomore-level courses open to large numbers of students not concentrating in multimedia studies.

COLLABORATION USING INFORMATION TECHNOLOGY

18. All departments and programs should examine ways in which collaboration, including collaboration using information technology, can become both an activity and a learning outcome in their courses.

19. The Center for Research on Learning and Teaching (CRLT) should mount workshops, in as discipline-specific a manner as possible, that demonstrate effective strategies for structuring and enabling student collaboration and that enable faculty and GSIs to understand and to teach undergraduates which collaborative tools are appropriate in different circumstances.

The Information Revolution and the Educated Person

Information has been with us a good deal longer than have universities. The mission of universities—to discover, to create and to disseminate knowledge—rests on the foundation of information. The "knowledge" that we create and disseminate is born of the discovery, analysis, synthesis, contextualizing, and theorizing of information.

Our issue in these two subcommissions, then, is not so much information technology, or the so-called "information revolution" per se. Rather, our issue is one of how we as an institution choose to address a series of facts around the deployment of new information technologies and media. These new technologies and media are increasing at unprecedented rates the amount of "information" available to the world. Most of this information, including that used by students and faculty, is produced and disseminated by people outside the academy. Much of it, in theory at least, is irrelevant to the pedagogical and research missions of the University. Very little of it is subject to protocols of evidence, authentication, and verification of the kind that have long characterized education and research in the University. And yet, its capacities, our access to it, the ways we use it, the ways we understand it, the kinds of analyses we bring to it, and the kinds of analyses it enables us to bring to bear on our disciplinary research and teaching are transforming the University, the workplaces our students will go to, and (directly or indirectly) the lives of all of us.

What does this mean for education in a large, public, research university? What should we be teaching with regard to this "revolution" (or perhaps more properly, "evolution"), how should we be making use of the opportunities it offers in our teaching, and whom should we be teaching? How can we create a university environment in which students and faculty are comfortable with and open to uses of information technology? Large questions, these, and questions to which, despite the voluminous and growing body of punditry on the topic and the growing body of academic IT initiatives we can find described daily in the online Chronicle of Higher Education, we found but little help in the public or scholarly domains. The subcommission has consulted with figures such as John Seely Brown and Lawrence Lessig and debated their ideas with some vigor. We have read the Information Technology reports produced in the last few years by many of the major universities in the United States only to discover nearly all remain preoccupied with getting computers on the desks of faculty and students and do not address these larger questions. We have read the report on "Being Fluent with Information Technology" produced by the National Research Council and its articulation of concepts students ought to learn with regard to information technology has been important to our deliberations and recommendations.

We have entertained a variety of faculty and staff from across the University as informants to the commission. Some of these people who have been so generous with their time have been most helpful in informing us about what the University already does to ensure that students have adequate information technology "skills" as they begin their work here. Others have provided some wonderful examples of pedagogy on campus that is furthered by the use of information technology, and still others have sought to educate us about what we should understand as the proper subject of education lying behind that catch-all phrase, "information revolution."

By means of an invitation to respond via e-mail and in two forums, we also invited faculty from across the University to give us their ideas about appropriate learning outcomes with regard to the information revolution. They offered us much in the way of ideas and opinions and very little by way of consensus: some faculty believe that every student should become a competent programmer while others believe that the new technologies have—or should have—nothing to do with them, their disciplines, or their university. A small group of students, most of whom attended both forums, urgently requested better support of their learning through access to training sessions for specific skills, and, much more ambitiously, through the introduction of new programs, especially in multimedia. And those of us who meet alumni frequently heard over and over again that graduates without the capacity to work with and in information technology will not be hired.

Our committee members have struggled with a sense of irony and frustration as we have muddled around our task for the last six months. Our topics—"what and how we should teach" with regard to the information revolution—have been too broad to get a sure grip on. At the same time, they are characterized by an absence of the kinds of empirical analysis and deep ratiocination which universities wish to inform their decision-making. Moreover, the information revolution, or as one of our members aptly calls it, the "information evolution," is moving more quickly than any academic commission does or can.

Not quite mired in this dilemma, we sought guidance in the notion of what it means to be an educated person—to be able to swim with sureness and adaptability in one's society and one's physical world. To be educated is to know something of the history, the cultural productions (in music, art, literature, film, religion, etc.) and the legal, political, economic, and social systems of at least one's own society. It is to understand something of the inter-relatedness of one's own and other social, political, and economic systems. It is to know something of the physical laws of the universe and of the history of science and medicine. It is to be able to use effectively the "everyday technologies" of our lives, to understand their implications for our society, and to be able to shape those implications through shaping the technologies and/or their use.

Information technologies are "everyday technologies." Virtually every household in North America has a television; most have VCRs. The household without chip technology embedded in a clock, a radio, a timer, is hard to find. Over 50 percent of Americans now have access to the Internet and use it regularly; a much higher percentage of those with college degrees use the Internet regularly. Eighty-five percent of U-M students come here owning a computer. Ninety-seven percent use e-mail regularly.

To be "educated" today is, in addition to much else, to be able to swim easily in the world of the information revolution. It is to know something about the "information evolution" of the last fifty years and of its social, cultural, economic, political, legal, and psychological implications. It is to be able to use information technology wisely, strategically, ethically, effectively. It is to be able to "read, interpret, and apply" contemporary information produced or presented by means of this technology. It is to be able to deal with data sets using this technology. In a world of multimedia, it is to be visually and aurally literate. It is to be able to "manage" the vast amounts of information now available, to be able to think about "information systems," and to be able to make accurate judgments about the accuracy and value of any particular "information."

To be educators in a world in which the technologies and effects of the information revolution are ubiquitous is to go well beyond the IT "skills" training that characterizes much of the public call to higher education around questions of information technology. It is to reach for learning outcomes that are an integral part of our disciplines and our curricula. It is also to reach for learning outcomes that address the subject of the information revolution in its own right, approaching it with the same rigor—the same attention to historical evidence, empirical data, and discourse analysis—that we demand of the rest of our research and teaching. It is to create a campus environment open to, comfortable with, and intellectually excited by innovative uses of information technology and their ensuing consequences, intended and unintended.

Information technology can potentially influence how we teach by enabling the more effective use of faculty time and resources, by developing modes of teaching that enhance traditional classroom experiences, and by reaching new groups of students who would otherwise be unable to participate in University of Michigan classes because of barriers of time and location. The two subcommissions believe that the enabling capacities of information technology, coupled with genuinely academic learning outcomes relative to the information revolution, will allow faculty and students to cross more

easily the teaching/research divide that characterizes the work of many faculty teaching undergraduates. We see possibilities for dissemination of research findings to much broader audiences and in formats other than classes and publication. We think these possibilities will enable faculty to share their intellectual preoccupations—often in interactive ways—with more students and with a broader range of students (including alumni) and with the broader public who call for increasing accountability for the use of public monies than has been the case in the past.

The Current Situation at the University of Michigan

There is reason for cautious optimism about the University of Michigan's capacity to take a leadership role in education with relation to the information revolution. While there are pressing needs in the areas of infrastructure, learning resources for students, the development of curricula, and faculty expertise, there are also many notable successes. We see a base that places us in a strong position on which to build.

Physical and Human Infrastructure

A comparison of the University of Michigan to other institutions reveals that we have a comparatively sound physical infrastructure for instructional IT. The basic backbone network is reasonably extensive, providing telecommunications support adequate to current usage levels both within and outside the institution. Most buildings have fiber-optic "towers" from which wiring is run to offices, classrooms, and laboratories that require an Internet2 level of access. A number of classrooms and educational spaces are outfitted at some level for multimedia and IT, and this number will grow significantly over the next four years as the undergraduate life sciences building and the Phase II LS&A renovations on Central Campus are completed. More advanced or specialized facilities for classroom use are presently available in certain areas of the University (e.g., the Media Union).

Still, the level of infrastructure for teaching with and about information technology varies considerably across campus. Colleges and schools deliver much of the programming, all of the equipment, most of the technical support, and most of the renovations that get fiber-optic cable from the door to the desktop. Despite the generally acceptable level of network infrastructure for current needs, there remain pockets across campus in which faculty do not have access to an adequate level of connectivity for their teaching and research. And a significant proportion of classrooms is not equipped for teaching with or about information technology. In the 1999 survey of Faculty IT Uses and Needs commissioned by the Chief Information Officer, faculty identified the following desirable technical facilities as missing from the classrooms in which they taught: Internet access (18%), network connection (17%), computer projection (27%), student computers (15%). In some areas of campus, these figures would be much higher than these averages.

New or very recently renovated buildings often have a higher level of technology infrastructure than does the rest of the campus, and this too introduces variations from program to program in the availability of "media smart" classrooms and laboratories. Many classrooms in even fairly recently renovated buildings are not yet "media smart"; this tends to be particularly true of smaller classrooms. Other buildings have been placed on a schedule for renovations, but their occupants find that these renovations may be as many as five or more years into the future and that, meanwhile, very little is being done to bring them up to current standards with regard to information technology. In some instances these buildings house programs that are technology-intensive in terms of the use of technology in teaching or in terms of technology as the medium of the subject they teach. (We note that the Frieze Building poses a particular problem. Basically a pre-WWII un-renovated high school, it houses two departments with technology intensive language teaching programs. It also houses the Department of Communication and the Film and Video program, both of which should both study and use sophisticated media technology.) Poor technology infrastructure is actively hampering research and teaching in these disciplines.

Despite the reality of variable resources, and the actual fact that resources are "higher end" and more ubiquitous in some areas of the campus than others, the colleges and schools have established a good hardware and software base. Virtually all faculty (i.e., all faculty who have not refused them) have computers, and these are replaced on a regular and viable cycle. Eighty-five percent of undergraduate students own computers, usually high-quality equipment. Dormitories are well connected and students have access to computers in many labs around campus, both near their classes and in their dormitories.

Hardware and software are necessary but insufficient preconditions for the effective deployment of information technology as both a subject and a medium of pedagogy. At least as important is the human infrastructure that ensures that the equipment is working and that allows for training of faculty and students in the use of this technology. Here again significant variation exists from school to school (indeed, in many cases, from department to department within the same school). Not surprisingly, the demand is keen for support personnel who have some discipline-specific knowledge and understanding, and who can work closely with faculty and students on IT-related research or instructional problems that are intellectually context-sensitive (as almost all are). In the 1999 Faculty Survey at Michigan, the majority of respondents (66%) indicated a wish to learn IT from peers or others familiar with their work, an observation with direct implications for support structures, pointing towards the desirability of more "person-to-person, side-by-side" models. Also increasingly clear is the emerging need for new help for faculty in dealing with the changing landscape of intellectual property legislation.

More generic training resources for faculty include workshops on the use of information technology in the classroom, offered by the Center for Research on Learning and Teaching, and the Library's Faculty Exploratory. The development of "CourseTools" by the Information Technology Division's OIT group was the result of a collaborative effort between CRLT and ITD funded by the Deans' Partnership program, and has facilitated faculty integration of information technology into their courses. The

package is generally received as easy to use and has been taken up rapidly by faculty members. Within a very short time, it has become the most widely adopted instructional use of information technology within the University. Several recent developments in the provision of online information resources have proven particularly effective in encouraging the use of information technology in teaching and of teaching about the information revolution. The Library has been putting together a set of online resources in selected areas and has done much to facilitate the use of the Internet as a research tool. It has also greatly expanded the online availability of full-text journal articles and access to online databases; both these initiatives offer faculty an opportunity and a challenge in keeping up with IT developments.

What Faculty Know

In 1999, the University of Michigan Chief Information Officer and the Faculty Senate Advisory Committee on University Affairs surveyed Michigan faculty on issues involving information technology needs and uses. Out of 1,500 surveys distributed across the Ann Arbor campus, 743 faculty responded. While not a perfect sample, some care was taken to ensure that it did reflect the attitudes and practices of a range of faculty, and not merely those of the more sophisticated users. These data, then, can be taken as providing some insight into faculty capabilities and shortcomings with regard to their integration of information technology into teaching. We offer them, however, with two caveats: one about the sample, as discussed above, which may overrepresent more sophisticated users, and the second about the fact that this survey was being done just as CourseTools was being rolled out. We think it likely that the availability and relative ease of use of CourseTools has substantially increased the faculty integration of information technology into teaching over the last eighteen months. (An updated survey is currently in process, and the results will be available in the summer of 2001.)

The survey data show that IT is clearly part of the daily life of almost every Michigan faculty member. Of those who responded, 99% of full professors with tenure and 100% of associate professors with tenure use a computer every day, in their offices or their homes. 95% of respondents report using IT tools every day. Some statistics:

- 99% used e-mail; 97% used word processing, and 94% used web browsers.
- Over 75% of faculty respondents use a spreadsheet application, and 66% report using presentation software, such as Powerpoint.
- Close to 50% of respondents report using graphics, 44% publishing, 44% database, 42% calendaring, and 41% statistics software; 32% report using a web editor; 26% use multimedia; 23% use web software; 22% use modeling software.

In all, some 83% of all respondents rated themselves as intermediate to advanced computer users; 8% rated themselves as expert. By contrast, only 0.3% report not using computers at all.

As far as teaching and student interaction is specifically concerned, 66% of the survey respondents believe that IT is important to their students' success, and 59% use IT to collaborate with both col-

leagues and students. In 1999 when the survey was taken, 23% were using the Internet and Web in course delivery and administration (compared to 2% in 1996). Since then, the large-scale U-M CourseTools pilot has been launched on the Web. For fall semester 1999 and winter semester 2000, 9,000 class sections (out of over 21,000 class sections) have used CourseTools. While it is too soon to fully assess the efficacy of CourseTools, it is clearly being utilized in a variety of fashions, with some faculty taking full advantage of all its possibilities and others working in a far more basic idiom.

As the section on Faculty and Graduate Students (Graduate Student Recommendations) and the appendix of this subcommission report demonstrate, numerous innovative teaching projects involving IT are already underway at Michigan. What also emerges clearly from the 1999 survey is a strong general interest in expanding IT use in the classroom and in expanding it in a number of directions. When asked what resources they would like to use if they could easily obtain support and service, 59% named a web page with course materials; 55% an e-mail list of students; 54% audio/video clips, animation, and slides; 53% a class electronic bulletin board; 42% computer simulations; 35% multimedia presentations as class assignments; 32% self-paced practice and tests of routine tasks; 25% writing tutorials; 20% audio-video for remote teaching; 16% textual analysis programs; and 15% video streaming.

Despite this healthy interest, one measure of the gap between what faculty would like to do and what they can do is offered by this statistic: while 85% of faculty use IT more now than they did two years ago, some 63% report lacking the skills they need to use what they want to use. The latter number varies from school to school (with, for example, more faculty from Music or LS&A lamenting that "I have not acquired the necessary skills" than from Engineering or the School of Natural Resources and Environment), but this is a concern everywhere. The strategies to overcome this obstacle will be addressed elsewhere in this report. Meanwhile, we would simply hypothesize that some of this difference is due to disciplinary differences in the extent to which the information revolution has expanded capacities for collection, analysis, and presentation of data: the greater the expansion of capacity, the more information technology has become integral to the discipline. In such venues, the use of information technology will be part of nearly every course, faculty will be able in its use, and classrooms, laboratories, and student learning centers will be comparatively well equipped. In other areas of campus where there has been less integration of information technology into the discipline and, therefore, into the curriculum, IT nonetheless still plays a strong role in particular applications, as in language teaching which is supported by a highly computerized Language Resource Center.

What Students Know

In general, students entering the University of Michigan are relatively sophisticated and on average probably more sophisticated about information technology "skills" than are faculty. Most students arrive with basic proficiencies, such as e-mail usage, word-processing, and use of a web browser. Some statistics, drawn from the 2000 Orientation Survey for incoming first-year undergraduates at the University of Michigan:

• 92% had Internet access from home.

- 76% have used the computer at least weekly for writing assignments.
- 84% access e-mail at least once a week, and 60% access it daily.
- 73% look at web pages at least once a week.
- 54% of incoming students believe they have strong computing skills.

These results, compared to past years, suggest that the average student level of IT sophistication is constantly on the rise and that this will continue.

At the same time, not all students arrive equally prepared with even basic skills; students from more affluent schools generally have had more practice with IT than those from poorer schools. And there is inevitably adjustment to the new computing environment in which students find themselves. To enable this transition, the University assigns all students a unique name as they accept admission. This unique name appears on class lists, facilitating instructors' use of IT in pedagogy. During orientation, the Admissions office in collaboration with ITCS runs an excellent session to ensure that all students know how to get access to their e-mail and the web. Students are also provided with printed material that serves as a reminder. ITCS also runs workshops for students that enable them to acquire skills about particular software packages (e.g., Pagemaker). These were free at one time and now are charged for, a matter of concern to students who came to the forums. ITCS provides access to NetG online access to over 200 interactive courses to university faculty, staff, and students at no charge.

Both anecdotal evidence and data suggest that sophistication among our students about IT does not necessarily go much beyond word-processing, e-mail, and rudimentary Internet searches. Some further data from the 2000 Incoming Student Survey:

- 40% have never used a database or a spreadsheet, and only 18% have managed data on a computer at least once a week.
- 64% have never created multimedia graphics or sound.
- 71% have never created a web page.

Faculty report that students are not at all sophisticated in matters of information technology "fluency" (i.e., understanding the concepts underlying digitization or the ways in which computing hardware and software are structured). And they are even less informed about matters of information as opposed to information technology: about how to analyze and evaluate the information one locates by means of the technology, and about the larger social, moral, economic, political, legal, and cultural dimensions of the information revolution.

While we have data about what students know about information technology when they enter the University of Michigan, we have no data about what they know about information technology and the information revolution when they leave. Classroom practice makes it clear that many learn a good deal about such technology by "doing it" in their disciplines. Assignments requiring or encouraging the use of IT are done with the more or less systematic or ad hoc help of peers, GSIs, and occasionally faculty

members. We believe, but cannot document empirically, that many leave with precisely those skills in database and spreadsheet use that are wanting when they enter. Some will leave with a clear sense of the relation of hardware to software and of how different applications work at the technical level. Students generally acquire the ability to assess the quality of "information" through disciplinary practice. We have no evidence as to whether instructors are incorporating into their teaching specific instruction as to how to evaluate information from the Internet or as to whether students are readily transferring to the Internet skills in critical evaluation that they learn with reference to printed materials.

Current Teaching with Information Technology

Faculty use information technology in their teaching in ways ranging from the simple to the sophisticated. Some simply "translate" more traditional paper-based instruction into this new medium. Others venture further, using the technology to "supplement" more traditional modes of teaching and to introduce new modes of interaction among students. Both Physics and Math, for example, are developing such materials. The University has a strong cadre of "early adopters," developers and implementers of information technology among both faculty and students who have provided us numerous and exciting examples of the effective and innovative integration of information technology and digital media into courses and student projects. At the same time, in some areas of the University, including language courses, the natural sciences, engineering, and business, there is already fairly extensive integration of information technology into the curriculum. Math, for example, now teaches the use of general purpose software to large sophomore courses not only to "train" students in the use of the software but because it permits the assignment of problems that enable the students to learn mathematical concepts better. As CourseTools allows more courses to be put up on the Web, students are readily adapting to the medium.

Applications of IT in pedagogical contexts may be broken down into five principal categories: 1) course management; 2) presentation; 3) practice and discovery; 4) research as a part of teaching and learning; and 5) communication and collaboration disciplines. Below we review each of these in turn, providing specific current examples from within the University of each; for documentation of these and other cases, the reader is referred to the Appendix.

Course Management

Michigan faculty employ IT to undertake various administrative tasks associated with instruction. Although distribution of text-based materials (syllabi, course materials, handouts, articles, etc.) is perhaps the most common, faculty members also distribute audio and visual resources with IT (video of lectures, audio clips of lectures accompanying PowerPoint slides, and other visual artifacts). They also maintain electronic grade books for themselves and for GSIs in multi-section courses and use other work group management tools to maintain organization with materials and student work.

Presentation

Presentations delivered with a tool such as PowerPoint most commonly address basic in-class instructional needs—electronic versions of overhead transparencies and chalkboards. Faculty members also use presentation tools to outline issues, illustrate points, provide visual cues for quotations, and share visual resources with all participants simultaneously. Some faculty members incorporate web links or video clips demonstrating abstract issues or providing access to resources not otherwise available in the class setting. Other faculty encourage students to prepare and deliver oral presentations with IT tools, allowing students to complete all aspects of the presentation in advance, and allowing faculty members to review or evaluate the presentation (including supplementary resources) outside of class.

Practice and Discovery

The category of Practice and Discovery entails two types of usage: a) Practice and Review and b) Exploration and Simulation. When faculty members employ IT in order for students to practice and review specific course materials, they often turn to interactive exercises, problem sets, tutorials, or other types of lessons, which students would undertake outside of class or independently. Typically, electronic workbooks and interactive exercises to develop targeted skills or to facilitate remedial instruction would be available online, on the web, or on a CD-ROM. Some publishers even provide workbooks and exercises on CDs accompanying their textbooks. These practice and review applications provide a student with sufficient guidance and feedback to complete activities that once required the presence of the faculty member. This category also includes self-tests, quizzes, exams, and assessment tests, which allow students to receive important input on their performance when the instructor is unavailable. Instructors may use practice and review applications to enhance in-class activities - these then become innovative community building activities that provide important jumping off points for in-class discussions.

The discovery-oriented aspect of this third category is more apparent when students and faculty use IT to facilitate exploration and simulation. These types of tools are another way in which the instructor attempts to bring the external environment into the classroom—by taking students on a virtual field trip to a distant time or place. Exploration and simulation applications can also assist the instructor to illustrate abstract concepts and complex systems through animation or modeling. These same tools also provide the opportunity for students to explore materials, concepts, and situations independently—providing the opportunity to practice over and over before setting foot in a laboratory or meeting a patient face to face. Similarly, students can access interactive case studies either individually or in groups.

Research as Part of Teaching

While research has always been a significant part of instruction at the University of Michigan, faculty members employ IT to improve the connection between students and faculty research in two ways.

The first is by improving students' access to information previously available only to the primary members of the research community. Even in the most introductory courses, faculty members are able

to provide their students with access to scholarly information and resources for sophisticated analysis and examination. This might be web access to digital libraries, media delivered on CD-ROM, or improved access to primary resources via digital reserves, online publishing, or detailed, hyperlinked citations. Students and faculty are able to share their newly discovered information and resources with classmates via shared workspaces and showcases. They can also conduct their own exploration of primary data (e.g., survey data and remote-sensing data) and examine graphic display of quantitative data.

The second way in which IT allows the faculty to incorporate research more successfully in teaching is by providing students with the opportunity to become actively engaged in the research process and transform themselves into co-investigators and colleagues. This can take the form of semester-long research projects that are shared on the Web for discussion and critique or in the form of student research that becomes part of an ongoing database of resources for future course. Students and faculty are able to share their research resource portfolios and design modeling with each other and with the greater academic community. Students and faculty also can create virtual events, such as installations, exhibitions, galleries, and interactive artistic events.

Communication and Collaboration

Michigan faculty employ Information Technology to improve communication and increase collaboration in instruction in many more ways than the ubiquitous use of e-mail. Instructors facilitate discussion in synchronous and asynchronous environments. They hold virtual office hours in chat rooms and post answers to individual student's questions to class bulletin boards so that all students may benefit. They organize live online discussions with students in multiple locations to encourage diversity of input. Faculty members invite experts, informants, and native speakers to participate in webcast conferences so that students are able to come in direct contact with people intimately involved in their field of study. Instructors provide complete anonymity and therefore full freedom of expression in online discussions of highly sensitive subjects.

Instructors also use IT to encourage improved collaboration between students. This might begin in the form of peer editing or peer review for content or writing and graduate to coordinated student group research projects. Many faculty members encourage submission, editing, and publishing of multi-author documents via e-mail or the Web. It also includes collaboration between students at multiple institutions and collaboration between faculty and students in multiple locations exploring different aspects of the same issues.

All of the above activities are also employed in multi-institutional and cross-national instruction. Michigan faculty members use IT to teach collaboratively and simultaneously with other universities in order to take advantage of unique faculty strengths or rare resources. It allows students who otherwise would not have contact with Michigan faculty the opportunity to participate in exceptional learning experiences. Furthermore, communication and collaboration resources also provide Michigan students with the opportunity to work with students and faculty at other institutions in genuine international partnerships.

Finally, Michigan faculty and students utilize Information Technology to facilitate the most fundamental communication and collaboration needs—namely, to create access to previously inaccessible materials for students and faculty with disabilities. Michigan's Adaptive Technologies Site is jointly sponsored by the Shapiro Undergraduate Library, the Office of Services for Students with Disabilities, and ITCS. Located in the Shapiro Undergraduate Library, the site is an ergo-assistive work-study environment with variety of specialized hardware and software to accommodate the information technology needs of physically, visually, learning, and ergonomically impaired individuals.

In addition to projects internal to U-M, a burgeoning number of online resources for teaching and research beyond the institution see participation by our faculty. A number, for example, are working with the MERLOT project, which is intended to identify and evaluate teaching innovations and to make them widely available through the Internet for adoption. In November the University announced its partnership in Fathom.com; this will enable faculty to put various credit and non-credit courses online for dissemination to a much broader audience than currently registered students and to connect their courses with other resources available online. There may be a particular potential here to keep our alumni as "life-long learners." Finally, discussions are ongoing with unext.com, a consortium offering for-credit courses in business executive education and seeking to expand its offerings in the social sciences and the humanities.

Current Teaching about the Information Revolution

With respect to the larger issues around the information revolution, there are several cadres of faculty already addressing aspects of the information revolution, ranging from the technical to the social, in their courses. There are considerable intellectual resources for grasping the information revolution in all its dimensions. We would cite the Library (e.g., its Humanities Text Initiative, its Digital Libraries Initiative, its educational programs, and its support for skills development). The Schools of Education and Business Administration teach about information as a set of systems. And the School of Library Studies, by transforming itself into a School of Information, made the larger study of information revolution issues its major mandate (the SI, at the moment, teaches only graduate professional students). The School of Art and Design and departments such as Electrical Engineering and Computer Science, Communications, and Film and Video, to name only a few, teach about the new media and information technologies and their implications. This suggests that we can respond, at least partially, to questions of what we should be teaching.

There is also a growing recognition of the need to readjust some organizational and curricular structures to address the intellectual questions raised by the information revolution. This recognition is accompanied in many instances by a willingness to act. Among other initiatives we would cite the rethinking of the Computing Science and Computing Engineering degrees that has just been completed and the proposal for a new joint B.A./M.I. Organizational Studies degree that will include a much higher component of information systems.

There is, in short, a lot here. It has developed in a manner that Michigan faculty and students will recognize easily: as a series of distributed individual initiatives that have often received considerable financial support but that have not always been well coordinated with what might be going on elsewhere. These initiatives have developed without a clearly worked out university-wide sense of purpose or enabling policy.

Moreover, numerous if scattered examples to the contrary notwithstanding, we have, as an institution, paid relatively little attention to questions of information—as opposed to information technology—in the curriculum. We have not yet addressed systematically the assessment of information presented in multidimensional or unregulated media. Analysis of visualization, development of visual literacy, understanding of the relationship of textual and visual elements, and understanding the social and cognitive effects of moving between the physical and virtual: these are underdeveloped areas of study on campus. And there is little evidence that we are paying adequate attention to teaching students how to assess the unregulated "information" that comes over the Internet.

Faculty and Graduate Students: Creating a New Institutional Environment for Learning about the Information Revolution

A university such as the University of Michigan can and should assume academic leadership in learning and in scholarship about the information revolution. It also can and should assume leadership in the use of information technology in teaching and learning. If it is to do so, it must create for faculty and students an environment in which their efforts to understand the information revolution and to use technology for educational ends are encouraged, enabled, and rewarded.

Physical and Human Infrastructure (recommendations 1-3)

While another subcommission will be making recommendations about the University's IT infrastructure, a report on teaching in the information age can hardly afford to overlook this issue. Without the ready availability of "smart classrooms" and other networked sites, the extension of IT in teaching will be deeply constrained. We have already stated that certain features of the University's physical infrastructure are adequate to meet some basic needs; what remains to be said is, of course, that levels of use are expected to rise significantly in the near future. Even now faculty and students report a high degree of frustration and numerous problems with the infrastructure in the classrooms and the computer labs: printers, microphones, projectors, computers, and connectivity too often do not work. Faculty interest in expanding IT use in the classroom and elsewhere, coupled with mounting student expectation, requires rapid improvement of the University's infrastructure.

Recommendation 1: The University should make it a priority to equip a much larger number of classrooms than at present with network access and a significant number of classrooms across the campus with multimedia access.

No less critical than physical resources is the human infrastructure necessary both to maintain equipment and provide instructional support. Without this, frustration will supplant good will, and large numbers of faculty will not adopt information technology. All colleges and schools report a level of investment in IT personnel that significantly exceeds support for infrastructure increases in other areas. And yet the level of demand, along with the local labor market for IT personnel and the fiscal realities of the University, make the provision of adequate technical support an ongoing challenge in every area of campus and an unmet challenge in many areas. Support for information technology is often inadequate, or is not available when and where it is needed (i.e., in the classroom or at the faculty member's desk). The recent survey of faculty uses of IT identified this as a major issue.

Recommendation 2: The University should invest significant incremental resources to ensure that technical help is available to maintain equipment in working order and that instructional help is available to work in a "side-by-side" model for faculty and graduate students seeking to use information technology in teaching.

In addressing infrastructure needs at both the physical and the human level, the University should recognize that different models will be needed in different disciplines and support centers. (It should also budget resources in a way that recognizes the recurring nature of these costs so that funding may be renewed on a regular schedule.) In some cases, for example, instructional support might well include "just-in-time" assistance, "traveling tutors," greater reliance on graduate students and undergraduate students in a "reverse mentoring" role, mini-grants for small projects and workshops, a website on intellectual property policies and procedures. It is important to emphasize that the project of instructing the instructors in this area needs to be highly visible and pervasive, housed not just in a handful of central agencies (the library, ITCS, the Media Union) but reaching out to the small services units as well as to individual departments and programs. Multiple options should be made available.

Without the contribution of thousands of staff members who provide services critical to its academic mission, the University would quickly come to a standstill. For our investment in training and other modes of instructional support to be effective, we therefore need to make a comparable investment in the training of staff throughout the University in the use of information technology.

Recommendation 3: All staff should be competent with the information technology applications in their area of responsibilities. New hires should be required to have this competency; staff in place should be required to upgrade their skills to competency. The University should provide the training programs that will enable this.

Dissemination and Coordination (recommendation 4)

As demonstrated elsewhere in this report, instructors throughout the campus use information technology in creative and highly effective ways. These individuals have not simply updated traditional courses by using computer-generated slides or relying on electronic rather than paper documents. Instead, they have taken to heart the ideas of truly effective education: their students are engaged, "active" learners; they demand that students think critically and then argue for and defend their ideas; their students learn by teaching; the present challenging problems that relate theory to the real world. And then they use technology to provide greater engagement, deeper involvement, more complex or challenging problems, or fuller exchange of ideas.

At present, however, awareness of such innovations remains very limited, with little cross-fertilization between units. This is perhaps the chief irony we have encountered in thinking about teaching in the context of the information age: there has been very little pooling of information from one area of campus to another. Many faculty might well be inspired and enabled to adopt new approaches and methods in their teaching if provided with access to relevant and stimulating examples, in a context including specific advice and encouragement. Side by side with better communication, we need an added emphasis on adapting or transferring successful applications across disciplines, with concomitant attention to adequate support structures.

Recommendation 4: The University should create structures in which faculty, along with student and staff collaborators, work together and share their discoveries and expertise about information technology and teaching.

The Center for Research on Learning and Teaching (CRLT) has undertaken initiatives in this area within their broader goal of supporting teaching on campus. The University may want to develop an approach which explicitly focuses on IT in teaching and research. One possible model for such a structure is the Humanities Institute; another, perhaps better because it stresses course development, is the Sweetland Writing Center; a third is the Beckman Institute at Illinois; a fourth might be the Center for Advanced Computing in the Humanities at the University of Virginia. There are of course many other models for coordinating and promulgating existing as well as developing activities in this area. For example, the University should consider instituting, on a regular basis, a series of workshops or forums, with speakers knowledgeable about the information revolution and information technology, each speaker relevant to a group of cognate disciplines. Such visits could arise in the context of departmental and program agendas and plans for implementation of curricular initiatives about the information revolution. Invitees might be asked to teach classes in addition to offering faculty workshops.

One final caveat is worth making with respect to the gathering and sharing of best practices in this area. We need to recognize that technology can inhibit as well as facilitate effective learning. Ideally, IT can improve details of course management, methods of course presentation and delivery, and the processes of practice and discovery within the classroom. In the worst case, IT can "lock in" poor

pedagogical practices or block student-faculty interaction. This makes it imperative that we evaluate the use of information technology with the same metrics that we use to evaluate other innovations in teaching. To justify adoption, a technological innovation should either make teaching more efficient (allowing the instructor to spend more time on critical tasks and less on "routine" business) or make teaching more effective (increasing the depth or breadth of student learning or reaching more students). Technological innovations that improve instruction merit wide adoption; those that inhibit learning should be abandoned. These common sense assertions suggest that the University should foster an "ecology" of technological innovations in which some innovations are allowed to fail if best practices for the deployment of IT in teaching and learning are to evolve fruitfully.

Support Structures (recommendations 5-8)

Even as the University works more proactively to inform faculty members of the positive aspects of teaching with IT and about the information revolution more generally, it faces an equally pressing challenge. For the majority of faculty, the pressures of teaching, research, and administration leave little freedom to explore new options, especially those involving a substantial investment of time and labor. In the 1999 Faculty Survey, 55% of the respondents identified the time it takes to learn and use IT as the greatest barrier to their use of the IT applications or media they wish to adopt for pedagogical purposes. (64% ranked lack of time as their first to third largest barrier around using IT in the classroom.) Issues of time management, incentives, and rewards are clearly critical for faculty who might wish to adopt information technology in their teaching but who do not feel able to do so at the present time. Here too models are also critically necessary.

Recommendation 5: The University should establish processes by which faculty apply for release time specifically in order to establish or improve the instructional technology component of a new or existing course or to participate in the curricular development of new minors or concentrations on some aspect of the information revolution.

Expectations governing tenure and promotion at Michigan can likewise make it counter-intuitive to devote significant time to the development of new instructional technologies and practices. While concern for good teaching is already a high priority at Michigan, faculty recognize that promotion and tenure committees place at least as high, if not a higher, premium on strong research evaluated by long-entrenched metrics. Heavy personal investment in instructional technology has little or no automatic payoff in non-pedagogical aspects of professional life (e.g., in publication or other areas frequently assessed in the tenure and promotion process). The time it takes is time taken from activities more likely to lead to tenure, promotion, and merit increases. Moreover, lack of clarity about issues of intellectual property is another likely inhibitor of some faculty efforts in these directions.

Recommendation 6: College and School executive committees should accept innovative and effective teaching, pedagogical research, and research with instructional technologies as a positive aspect of a tenure or promotion file.

Recommendation 7: Issues of intellectual property with regard to courses developed by faculty and delivered by means of information technology, developed by faculty, should be clarified in ways that respect the interests of the faculty and the University.

Finally, with respect to hiring, it is reasonable to assume that competition for those pursuing interdisciplinary scholarship for which information technology plays a central role will be fierce. The same applies to those whose work engages the larger cultural and social implications of the information revolution. An aggressive and organized plan for the recruitment of such individuals is therefore timely.

Recommendation 8: The University should make target-of-opportunity funds available to hire faculty whose area of scholarship is in the information revolution, broadly conceived. These faculty should be cross-appointed to at least two disciplines or programs. These appointments should be distributed across the University.

We believe that the University can successfully fundraise for endowed professorships in this area.

Graduate Students (recommendations 9-10)

There is widespread anecdotal evidence to suggest that graduate students are especially well positioned to connect potential applications of information technology to emerging developments in their field. As the next generation of teachers, researchers, and skilled practitioners, they are of course expected not only to master the basic contours of their discipline but to contribute to its latest advances. With the increasing prominence of new technologies in helping to reshape many of these disciplines, it is not surprising to find that graduate students have frequently emerged as trail blazers in realizing unsuspected possibilities for IT in their field. Cases of reverse mentoring, where graduate research assistants guide and instruct faculty in this area, are familiar in the sciences and humanities.

Of course, not all graduate students are thoroughly fluent in information technology and conversant with the larger social implications of this new technology. For them, as for their more advanced peers, careful thought must be given to the learning opportunities they will need within the context of the graduate program. Some of this thinking must take place at the level of the disciplinary interests and trends generally; some will have to be undertaken in the context of the individual student's program. Where GSRAs or GSIs are involved, consideration should be given to appointing them to positions that will support development of new courses and curricula as well as faculty learning of instructional information technology. At a minimum, then, all units offering post-baccalaureate degrees should give attention to the particular fluency in information technology, and the larger knowledge of the information revolution, each student needs within the context of the discipline and to the creation of opportunities by which the student can acquire this knowledge.

The topic of graduate student teaching deserves separate mention. Irrespective of the level of knowledge about the information revolution that a graduate student requires as part of his repertoire of tools, methodologies, or even substantive intellectual questions, all graduate students should become

proficient in the use of information technology in the classroom. In particular we urge that GSI training, whether through the home department or through workshops in CRLT, include knowledge of CourseTools and other pedagogical applications. Graduate students should also be able to articulate in their work in the classroom the ways in which information technology is shaping their discipline. This is true even for those students who plan to go on to careers in industry, finance, or business, rather than academia; each of these careers requires presentation skills that use information technology.

Recommendation 9: Graduate students should be given numerous and wide-ranging opportunities to work with faculty in developing uses of information technology in courses and in developing courses/curricula about the information revolution.

Finally, graduate students, like faculty and undergraduates, benefit from having a community of learners sharing information and projects around information technology. As new technologies become more and more a part of a wide variety of disciplines and research agendas, the need for centers in which graduate students can pursue opportunities for collaborative learning both within and across disciplines will become increasingly acute.

Recommendation 10: A number of centralized information technology facilities, available to graduate students, and particular to their needs, should be established. These facilities should be devoted to areas of scholarly expertise that students from a variety of disciplines can draw on (e.g., the current GIS facility, computational modeling, large-scale database analysis etc.).

Undergraduate Students and Learning Outcomes: Creating a New Institutional Environment for Learning about the Information Revolution

Undergraduate Programs (recommendations 11-12)

Two-thirds of Michigan undergraduates are enrolled in a liberal arts and science degree in LS&A. Most of the remaining one-third are in the College of Engineering. Small numbers—by comparison, at least—enroll in Business, Education, Nursing, SNRE, Kinesiology, Pharmacy, and Dentistry. Our undergraduate degrees are replete with complicated sets of requirements that meet different educational aims. In this context, we do not think it productive to suggest a new series of requirements to be met by all students or even all students in any one college or school. Nonetheless, if an educated student is to leave us able to swim in a world in which the information revolution is having profound effects and in which information technology and the "information" it gives rise to is ubiquitous, this entails responsibilities on the part of the University. It is incumbent on the University to think through the role of the information revolution and information technology in each of its programs and to reflect those roles in its curricula.

Recommendation 11: Every undergraduate program should ensure that the significance of information technology and the information revolution is adequately reflected in the program's curriculum.

Bulletins of undergraduate courses in the different schools and colleges, as well as recruitment materials, brochures, and websites describing programs, should signal to students the desirability of understanding the implications of information technology and the ability to use it. Given the decentralized nature of the University and the stunning diversity of interests among our students, it seems unwise even to recommend any one course or presumptive set of courses as satisfying these goals. We therefore advocate a number of introductory courses, for credit, around the information revolution. These should include mini-courses, semester courses, or modules within a course. To assist students in identifying such courses, a special designation might be reserved for the relevant offering in any given discipline, just as students currently identify writing courses across the curriculum in LS&A or courses that meet the Race and Ethnicity requirement. (Please note that these are merely examples; it bears repeating that we are not making a case for adding a new requirement to the undergraduate curriculum.)

Recommendation 12: Schools and Colleges should be encouraged to adopt an "information revolution across the curriculum" approach to the teaching of the information revolution and information technology.

In view of the considerable differences between disciplines, Schools and Colleges will, of course, need to exercise their own best judgment about how to integrate such an approach into their curriculum in ways that give students "hands on" experience using information technology. At the same time, we do feel that there are certain core expectations that courses offered under the rubric of "the information across the curriculum" should meet. The final section of this report provides a broad outline of such expectations, identifying them in terms of desired learning outcomes.

Learning Outcomes (recommendations 13-19)

The heart of the subcommission's work focused upon establishing learning outcomes that our graduates should realize and upon offering a number of avenues and opportunities by which they can realize those outcomes. What do we want Michigan students to have learned after engaging with new technologies and after pondering their influence on our lives? As stated elsewhere and implied throughout this report, the information revolution is about much more than information technology per se. An educated student, one able to swim in the age of information, is one who understands something of the larger cultural and social issues and implications of the information revolution. Moreover, there are equally important questions surrounding visual literacy, conceptual understanding of basic computational processes, and collaborative learning that need to be addressed.

Understanding the Information Revolution and Evaluating Its "Information" (recommendation 13)

Before information can be properly valued it must be evaluated. Hence, we begin with a basic question: what constitutes information? Ongoing discussions of this question among committee members raised a number of **general observations and principles**. Among the most salient were the following:

1) Information is not the same as knowledge, and information dissemination is not the same as knowledge dissemination or "learning." Students need to learn that knowledge involves the use of information, but that knowledge is both personal and communal and the learning process has personal and social dimensions that information gathering per se lacks.
2) The existence of information does not guarantee communication. The Internet gives more people more access to some part of a worldwide communications network than ever before, and this is potentially empowering. But students need to know that the existence of web-based communication, divorced from conventional cues between speakers, can lead to miscommunication.
3) Information becomes meaningful only in a context. It is mediated, constructed, brokered, and presented in some fashion that carries with it particular aims, purposes and values. Students need to know that context matters and how to understand context. The interplay and relativity of forms and contents is important, especially with respect to multimedia which require visual as well as textual literacy to be understood.
4) The need to evaluate information and its reliability in a critical fashion, always true, becomes particularly urgent with web-based information given its leveling of sources and its lack of structure, convention, and protocols for authentication. Students need to learn how to evaluate this information.

Secondly, the **legal and ethical issues** arising from the information revolution should be a matter of explicit study. Among the learning outcomes we consider most deserving of attention we include the following:

1) Students should think not only about the validity and reliability of the information that they consume (students-as-readers), but also about the reliability of the information that they produce and disseminate (students-as-authors).
2) Students should be reflective about the responsible use of resources, and about the burdens certain kinds of private actions (e.g., MP3 downloads and spamming) place on public goods. Ethical considerations of when such private actions are acceptable, and under what conditions, should be habitual in students' thinking about the capacities of information technology.
3) Students should be knowledgeable and reflective about principles governing privacy, security, and access to information. They should be able to think about questions such as that of when limitation of access becomes censorship, or of who should have access to different classes of information.

4) Students should be aware of the complex legal and ethical issues (and their largely unresolved nature) around questions about ownership of particular information, about when information becomes intellectual property, and about the philosophical and commercial implications of open source vs. commercial software.

Lastly, there are the **social, cultural, legal, economic, political, and psychological implications** of information technology.

1) Students should be able assess cultural differences in the understanding of information content and in the use of information and information technologies. They should be able to assess the impact that information and information technologies have on particular organizations and groups within society and the ways in which people can shape the impact of technology.
2) Students should be able to assess the implications of the "digital divide," to evaluate how it changes one's place in society and what its role is in building social capital.
3) Students should be aware of some of the implications of the information revolution for globalization and multi-nationalism. They should be thoughtful about questions such as whether the information revolution promotes cultural hegemony or enables cultural diversity, or whether it should (or can) be managed to promote particular cultural and social goals.
4) Students should be able to think about the ways in which power structures respond in an "information economy," and about the implications of the information economy for the workplace, education, and entertainment. They should be thoughtful about the ways in which people attribute a value to information and about the impacts that pricing decisions have on access and use of information.

We recognize that not every student in every program will be able to meet all these learning outcomes to an equal extent and with an equal attention to the specific issues we have identified. As a broad summary, the following recommendation aims to distill the foregoing reflections.

Recommendation 13: Curricula at the University of Michigan should enable students to learn (a) to evaluate information and its reliability in a critical fashion; (b) to incorporate information into a field of knowledge so that it serves a specific purpose or intellectual goal; and (c) to become aware of some of the cultural, economic, and political implications of the information revolution together and to grasp the legal and ethical issues it raises.

Of course, there is no reason why the exploration of such issues need be restricted to courses devoted to the information revolution alone. On the contrary, the subcommission is of the opinion that any teaching that relies in some part on web-based sources or on students doing web-based research should also include explicit discussion of what constitutes information, and the legal and ethical issues surrounding information. By extension, a wide range of other teaching in the social sciences, sciences, professions, and humanities can and should usefully discuss the implications of the information revolution on our societies, economies, political systems, psychological functioning, legal systems, and cultural production. A significant number of the new appointments suggested in recommendation 8 should be in areas of expertise about these larger issues of the information revolution.

Fluency and Conceptual Skills (recommendations 14-15)

We have seen that while most students enter the University of Michigan with some computing "skills," those skills do not run very deep, nor do they appear to rest on a universally solid conceptual understanding of information technology as opposed to an ability to use "applications." Such students (and faculty) are not in a strong position to use information technology wisely. All students at the University of Michigan should be armed with the conceptual skills that will allow them to employ information technology wisely, both in their various academic disciplines and in their personal lives. Different academic disciplines use information technology in different ways, but certain key concepts and skills are universally helpful—not least in enabling people to comprehend and to adapt to ongoing, rapid technological change.

Thinking about the key concepts underlying information technology in different ways and at different levels of abstraction, we can distinguish between what information technology can do, how information systems work, and the hardware and data that underlie all computation. These three key concepts give rise to learning outcomes that all students should seek to realize.

One way to start to teach students to understand what computers and information technology do is to teach how they are embedded in information systems. An information systems perspective shows the relationship among the technical underpinnings of a system—its hardware and software—the data that it processes, the people who use it and are affected by the technology, and any processes or procedures that govern how the system is used. This perspective applies equally to computing in the sciences or the humanities, to large or small systems, to mundane or sophisticated tasks. A student who understands what an information system can do also understands what it cannot do—either due to an underlying difficulty in modeling or to a task's complexity that overmatches even the most powerful machines.

At the next level of abstraction, students should learn how information systems work. To do this they need to be able to appreciate and understand algorithms—that is, they should understand the procedures and unambiguous specifications of procedures that are essential to computer programming. They should understand the analysis of complex tasks into simple, unambiguous instructions that computers can follow. They should understand the "mindset" of the computer, and how it differs from the various modes of thinking in which humans engage. This understanding is useful for the construction of computer models as well as of other plans and specifications where it is important to consider all possible contingencies or combinations of inputs. (Understanding algorithms also hones critical thinking skills and an understanding of the structure of arguments.) Finally, algorithmic thinking implies the capability to "debug" faulty algorithms (or arguments).

Finally, students should understand conceptually the hardware and data that underlie all computation. There are, literally, tens of billions of microprocessors helping run the world today. Less than 1/100th of 1% are in computers. To understand the potential of this technology as it reaches ever deeper into our lives, it is vital to have some way to think about it without being overwhelmed by the details. Such

an understanding makes better-informed consumers—and critics—of information technology and information systems. It is predicated on knowledge about the basic elements of computation and their interrelationship: processors, memory, disk and other forms of storage, and devices for getting data into and out of computers. These elements are the basis of all "general purpose" and "special purpose" computers. Of equal importance is a basic understanding of computer networks and standards. An understanding of networks involves not only more technical issues (such as storage), but problems of authentication, security, and reliability, as well as the social issue of who can talk to whom. The topic of standards is chiefly concerned with compatibility—now and into the future. Again, the concern here is sharing of data and effective, harmonious communication—subjects which will become increasingly important to our students.

With this knowledge in hand, students will be in a stronger position to negotiate the present state, and future developments, of the information age.

Recommendation 14: Schools and Colleges should develop introductory information technology courses for credit that will realize the three learning outcomes outlined in recommendation 13. Sufficient sections should be made available to all students who wish to take them.

The University should consider hiring Lecturer III faculty to teach these courses. (The current introduction to computing for non-computing science/computing engineer concentrators might be a beginning model for such courses.) These courses could be integrated with those described in recommendation 12 above. In order to address a range of disciplinary issues around information technology and uses of information technology, they might be taught by faculty from a variety of disciplinary backgrounds.

Recommendation 15: At the same time, the University should develop, perhaps through ITCS, CRLT, or College and School learning centers, a series of non-credit workshops for students which address these concepts. These workshops might also be made available for faculty, staff, and graduate students.

Beyond these key concepts and skills, however, students will have various, more specific disciplinary requests of information technology. A student in the School of Music may be more concerned about the ability to transfer music files across various platforms, while an astronomer will be involved with the computation of gigantic data sets. Students must have the opportunity to develop capabilities and additional skill sets appropriate to their particular area of interest. Examples of these capabilities, many of which might well be shared across disciplines, include:

- An understanding that information systems are tools for modeling and abstraction. This involves understanding how to represent real-world phenomena (be it payroll taxes, weather prediction, or migratory bird patterns) as computer models and programs.

- A more advanced proficiency in algorithmic thinking. A knowledge of algorithmic thinking can provide valuable practical skills (such as writing macros, scripts, applets, etc., which are becoming the tools of skilled spreadsheet creators, website developers, and writers using word processors).
- An educated awareness of appropriate and inappropriate ways to "translate" data sets into graphic form, and of the possibilities of misrepresentation and misuse of such presentations.
- An understanding of the techniques of spatial analysis (e.g., geographic information systems) and of their conceptual underpinnings.
- The ability to understand the structure of multimedia presentations and to "read" such presentations in a sophisticated and accurate fashion.
- An understanding of the difference between textual and visual rhetoric and presentation, and the impact of information technology on this age-old issue.
- The ability to mange immense and complicated data sets, as well as the hardware necessary for such research.

We believe that these needs can be addressed through the implementation of recommendation 12.

Multimedia Communication (recommendations 16-17)

As the information revolution grows, so too does communication using multimedia, including video streaming, web pages, Powerpoint presentations, photography and other visual forms, audio (in all its forms), and tactile feedback (e.g., the new PC mouse that feeds back texture and touch, or fully immersive environments). This is a form of communication that our traditional, print-based education does not prepare us to use critically or with understanding.

Appropriate learning outcomes around multimedia will certainly address the reading, use, and production of multimedia content. They will also address the unique properties of multimedia, and the knowledge and skills relevant to those unique properties. But they will also require of students that they know how to fit multimedia communication into the basic knowledge set needed for any communication: the knowledge of how to do research, gather data, organize information content, deliver content, and gather, assess, and respond to feedback.

To be able think critically and deeply about multimedia content, students will need to be able to:

- Understand the ways in which the medium communicates its messages, in visual, spoken, dynamic (e.g., video) media, as well as in combinations of media types.
- Recognize the distinctive capabilities of each medium (when is a picture worth a thousand words?).
- Understand principles of rhetoric, visual syntax, and how multimedia content is used to make an argument.
- Understand principles of effective design and presentation of multimedia content.

- Understand the means and methods of distributing content whether in person, by networks, or with hard copy.
- Understand the difference between synchronous and asynchronous multimedia applications and their appropriate use.
- Understand the appropriate context for use of content, that is, how the medium of communication is tied to the purpose of the communication.
- Understand how to evaluate the effectiveness of the message, and to assess the quality of the information it conveys.
- Read, listen to, and interpret multimedia content and recognize and analyze the information it contains.

To understand technical applications in multimedia, students will need to be able to:

- Create content in a variety of media forms (e.g., web pages, Powerpoint presentations, video, graphs).
- Know how to store, back up, and protect content.
- Know how to use multimedia in collaborative projects and in other distributed environments.

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Students should understand the capabilities and limitations of information technology for collaboration. First, they should understand what opportunities for collaboration are offered by the more common information technologies. Most students arrive with an understanding that e-mail provides them with a free tool for communication and collaboration with a geographically distant second party and many have sufficient experience of chat rooms to know that this model of collaboration differs from the more private, one-on-one model of e-mail. During their undergraduate experience, students should add to this repertoire new tools and models for collaboration, such as writing or scientific collaboratories or video-conferencing. The aim is to have students understand that multimedia provides powerful new tools for collaboration that go well beyond text-based models and they should begin to learn how to use these models for collaboration.

Students should understand the models for collaboration that information technology most effectively supports. We expect undergraduates to develop a sophisticated understanding of collaboration and how to use IT tools to achieve productive collaboration. They should be able to distinguish between the kinds of collaboration that can be done through e-mail, chat rooms, conference call, and face-to-face meetings. They should know which IT tools are most effective if a group of people take sequential steps in developing an information product and which are most effective if members of the group simultaneously develop the product. They should know the advantages and disadvantages of using different forms of collaborations. All this is to say that this outcome is as much about understanding the capabilities of information technology for collaboration as it is about understanding its limitations.

Students should have experienced collaboration through the use of a variety of information technologies as part of their undergraduate experience. These experiences should include a variety of activities, from those involving small clusters of classmates to those involving larger groups of people some of whom are geographically distant. Students should have used a variety of tools to carry out these collaborative activities. In short, students should develop, through experience, an understanding of how IT tools enable collaboration and the choice of appropriate IT tools for collaborations in later life should have become "second nature" to them.

Recommendation 18: All departments and programs should examine ways in which collaboration, including collaboration using information technology, can become both an activity and a learning outcome in their courses.

Recommendation 19: CRLT should mount workshops, in as discipline-specific a manner as possible, that demonstrate strategies for structuring and enabling student collaboration and that enable faculty and GSIs to understand which collaborative tools are appropriate in different circumstances.

A Word about Distance Learning

This subcommission report does not make a recommendation about whether the University should undertake an institutional commitment to distance learning. A number of distance-learning initiatives are currently underway at the University, developed by graduate/professional or continuing education programs. While the subcommission does not believe that distance learning will replace the on-campus experience that characterizes our undergraduate programs, we do recognize that distance learning may present important opportunities for or threats to the University.

Our recommendations do, however, address issues that are central to the development of a distance-learning potential. Innovations in the use of information technology in collaboration and teaching apply both to campus-based classes as well as to distance learning. Another PIRC subcommission—the "eC2 subcommission" (focusing on outreach, business, commerce, community)—is considering outreach to "communities" beyond students traditionally enrolled on campus, and we encourage the University to study carefully the issues surrounding distance education. Our recommendations focus on how information technologies should be integrated into what and how we teach, but they also have implications for developing greater potentials for distance-learning. Encouraging on-campus teaching innovations by faculty will expand our distance learning capabilities and create an important resource if the University chooses to pursue future activities in that area.

...And Brief Concluding Remarks

One would be hard put to find a university in North America that has not established over the last decade at least one, and often several, committees and commissions to assess its information technology needs. In the face of the unprecedented demands for equipment that the new information technologies present (and the financial implications of those demands), such university commissions are generally long on recommendations about technology infrastructure and a good deal briefer, indeed most often silent, about pedagogy in relation to information technologies.

Our own report has its share of recommendations about information technology infrastructure, both physical infrastructure and the "human" infrastructure that provides faculty and students with the expert technical advice they need to use these technologies efficiently. (By "efficient" use, we mean that the technologies serve faculty pedagogy and faculty and student learning rather than become a time-consuming end in themselves.) Addressing the infrastructure needs identified in this report is a necessary precondition for the implementation of the learning outcomes we have identified as key to an adequate education about the information revolution.

Our mandate to address what and how we teach in light of the "information revolution" went considerably beyond the "infrastructure" issues that reverberate through information technology reports in one university after another, including our own. In asking ourselves what an educated person needs to know about the information revolution, we set aside early on the rhetoric of "skills," which tends to

characterize public discourse about education in "an age of information." This is not to say that a Michigan student would, were the recommendations of this report implemented, leave the University unskilled in information technologies; on the contrary, a much higher proportion of students would leave much more "skilled" in these technologies than is now the case. It is to say, however, that such "skills" would be the naturalized by-product of the larger educational aims which we think proper to the University and which we have tried to capture in the statement of learning outcomes, which is at the heart of this report. We have tried in this report to arrive at recommendations that would see University of Michigan faculty and graduates *educated* about information technologies: knowledgeable and analytic about their structures, the histories of their uses, their dissemination, their modes of communication, and their impacts and implications for many aspects of our disciplines, our lives, and our society. We have also tried to arrive at recommendations that would allow University of Michigan student and faculty scholars to take a leading role in the scholarly research and assessment of the information revolution itself.

Our report points out what we believe may be some ways of moving towards these aims. Between report and realization, however, lies the rocky road of implementation. We see several steps as necessary to implementation that we recommend to the University community. In the first instance, the University must, through its senior administration, address the infrastructure needs that will enable the pedagogical initiatives we have addressed. Most critically, these include the provision of support staff knowledgeable about information technology in discipline-specific ways, the hiring of incremental faculty who make the information "revolution" the object of their study, and the provision of resources to free faculty time to develop new curricula and courses. In the context of the availability of resources, departments, schools and colleges should then be asked to engage, collaboratively in many instances, in the curricular review and development implied in this report's discussion and recommendations. Finally, we would urge a broad inclusiveness of graduate and undergraduate students in discussions and plans to implement this report's recommendations.

Appendix A: Examples of Information Technology Applied to Instruction at the University of Michigan

Please note: This appendix, compiled by Monika Dressler, is not meant to be a comprehensive list of all innovative uses of information technology at the University of Michigan. The examples merely illustrate the wide variety of ways faculty members use IT to create unique instructional experiences for Michigan students.

Course Management

Syllabus, notes, lectures, visuals distribution, grade books, work group management

- Sherri Kossoudji (LS&A Economics and School of Social Work) uses online archiving of materials and discussions in order to improve accountability and consistency among instructors.
- Pharmacy requests feedback from its students twice per semester on the current curriculum using web-based forms. Student feedback is incorporated into future curriculum design and implementation.
- Steven Levine (School of Public Health) distributes lecture notes on CD-ROM for student class preparation, review, and remediation.
- Kay Erdman (Business School) uses online assignment submission and grading to model business communications.
- Frank Ascione (Pharmacy) uses CourseTools to distribute assigned articles to students in conjunction with questions to answer in a stepwise approach. Instructors check answers before class to find out where students are confused. Model answers are posted for students to refer to while working on the next assignment or studying for the course exam.
- Bobbi Low (School of Natural Resources & Environment) uses CourseTools to distribute reading assignments, exercises, and discussion points along with specific tasks to complete before, during, and after the discussions. (https://coursetools.ummu.umich.edu/2000/fall/snre/nre/415/001.nsf)

Presentation

Illustrate visual points, outline issues, lecture notes, student presentations, provide access to guest lecturers year after year

- Hemalata Dandekar (Architecture and Urban Planning) has had guest lecturers videotaped in order to add clips from their lectures to her PowerPoint slides to underscore points she makes. This means she doesn't have to ask the lecturers to come to her class year after year.

- Dennis Pollard (LS&A, Romance Languages: Spanish) incorporates video into PowerPoint presentations to illustrate subtle, yet critical, differences in Spanish grammar, which students in 5th and 6th semester courses consistently find the most difficult.
- Terry Brown (School of Natural Resources and Environment) integrated technology and active learning in the classroom with PowerPoint. His PowerPoint presentations clarify information and provide the opportunity to promote active learning.
- Qinghai Chen (LS&A, Asian Languages and Cultures: Business Chinese), Maria Dorantes (LS&A, Romance Languages: Business Spanish), and Janet Van Valkenburg (LS&A, Germanic Languages: Business German) have students learn PowerPoint (and other applications) as they acquire foreign language skills. Students give oral presentations for student projects in the target language with PowerPoint.
- Norman Hogikyan and Freda Herseth (School of Medicine) used technology to develop an interdisciplinary educational videotape for teaching the anatomy and physiology of voice to students of the vocal arts.

Practice and Discovery

Practice and review with interactive exercises, problem sets, tutorials and lessons

Electronic and web-based workbooks, interactive learning, exercises for targeted skills, remedial instruction, in-class review activities, formerly in-class exercises now completed outside of class, annotated texts, self-tests/quizzes, exam review, performance & readiness assessment, exam question database

- Scott Fogler (Engineering: Chemical Engineering) developed a four-hour junior level chemical reaction engineering course that is offered in a completely asynchronous environment. Chemical Reaction Engineering (ChE344), offered for the first time online Spring/Summer 2000, covers the fundamentals of chemical reaction engineering with emphasis placed on logic rather than memorization of equations and the conditions to which they apply. The material is divided into 20 units, which the student completes at his or her own pace. The main core of the learning process is the textbook. The textbook is supplemented by the CD-ROM, which accompanies the book, and the Internet. The lecture notes on the CD and Internet are interactive with a number of self-tests, additional examples and audio. In addition, there are interactive computer modules and a number of frequently asked questions for each chapter on the CD-ROM. (http://www.engin.umich.edu/~cre/)
- Donka Markus (LS&A, Classical Studies: Latin) created a web workbook that gives students an opportunity to practice concepts and skills leading to the acquisition of Latin sentence structure that cannot be transferred from English, because they are Latin-specific.
- Sugih Jamin (College of Engineering) uses computer supported learning modules to improve teaching network algorithms. The faculty built a virtual network emulator for the course so students can have simulated hands-on experience while learning network algorithms.

- Faculty in the Department of Physics developed the Computer Aided Physics (CAP) system to provide a unified gateway to course materials and grading for all large introductory classes (Physics140/240 and 125/126). CAP also provides students with individualized homework via the Web. Students submit their answers to the CAP system while they're working and receive immediate feedback. If they don't get a problem right the first time, they have the opportunity to try again until they do. The system also provides hints and encourages students to continue to work on their homework until *they* get it right. Since the institution of CAP one year ago, time spent by students on homework has expanded substantially, leading to significant improvements in student test scores.
- George Michailidis (LS&A, Statistics) developed web-based interactive statistics education tools (database of case studies and data from various scientific disciplines) to help students understand the intricacies of statistical thinking and data analysis.
- Timothy Mackenna (University of Michigan–Dearborn, Mathematics) created online math with streaming video and interactive exercises.
- Dawn Tilbury (Mechanical Engineering and Applied Mechanics) created Web-Based Control Tutorials for Matlab
- Serafin Coronel-Molina (LS&A Romance Language: Spanish) created two types of interactive PowerPoint activities for small group work in-class, class competitions, and general review: ¿Quién quiere ser Millionario? and Jeopardy.
- Johannes Von Moltke (LS&A, Germanic Languages: German Film) Uses CourseTools to deliver video clips and questions for detailed analysis which prepare students for in-class discussion on the following day, as well as provide semester review.
- Raji Rammuny (LS&A, Near Eastern Studies: Arabic) is creating a 20-lesson multimedia textbook for Arabic for Communication, including linguistic information, cultural information, original video, audio, and exercises with feedback. Lessons 1–10 are currently in use.
- Dennis Pollard (LS&A, Romance Languages: Spanish) created an application which leads students through ever-deeper levels of literary analysis by walking them through several viewings of a film and presenting ever-more complicated questions. The application contains video clips, a notebook with questions (which demand a minimum number of words before allowing students to continue), and a glossary of Spanish terminology.
- Rosina Lippi-Green (formerly of LS&A, Linguistics) created a multimedia annotated journal article on legal issues of language discrimination, which incorporates a variety of reference texts, audio and video clips, notebook, and workbook assignments. Application is currently used in Language and Discrimination course taught by Robin Queen (LS&A, Linguistics and Germanic Languages).
- Carolyn Anderson-Burack and Dominique Butler-Borruat (LS&A Residential College: RC French) created a multimedia French reader of annotated authentic texts with accompanying reading strategies exercises and cultural cues in order to bring out specific contextual clues found in the texts.
- Faculty in the Department of Mathematics (LS&A) have begun to deliver exams on basic skills over the Web (using either E-Grade or WEBWORKS) to students in freshman mathematics courses (105/

115/116). Students receive instant feedback on the correctness of their solutions. Practice exams may be taken as often as desired. Beginning in Winter, 2001, individualized homework assignments will also be delivered through these packages. Students submit their answers while working and receive immediate feedback along with the opportunity to try again until they solve the problem correctly.

- Scott Spector (LS&A, Germanic Languages) used Storyspace to create hypertext webs of authentic texts annotated with multimedia references on the German Historikerstreit, including a variety of primary texts, time lines, definitions, and exercises in thematic analysis.
- First, Second, and Third Semester French courses use a textbook, Portes Ouvertes, accompanied by a CD-ROM multimedia workbook; Second Year Spanish courses supplement their coursework with Nuevos Destinos a multimedia CD-ROM. Both of these materials were supplied by outside publishers and then incorporated into the traditional language classroom.
- Kathleen Kyndely (School of Nursing) created online tutorials and tests that mimic the online board exams the students must pass for their licenses.
- Pharmacy has been a heavy user of UM.Lessons for weekly quizzes on their students' comprehension of material. Instructors can then focus the following lectures on areas students have had trouble with.
- Barbara Weathers (LS&A, Chemistry) creates frequent online quizzes allow rapid feedback for students of introductory courses.
- Monika Dressler and Hartmut Rastalsky (LS&A, Germanic Languages) transferred the department's paper placement exam to Problem Set Framework/UM.Lessons and now have the exam (and instant grading mechanism) available on the Web, allowing immediate feedback and course advising.
- Qinghai Chen (LS&A, Asian Languages and Cultures: Chinese) created a CD-ROM based Chinese Listening Comprehension Test in Foreign Trade.

Exploration and Simulation

Bringing the external environment into the classroom, virtual field trips, cultural exploration and examination, case studies, virtual labs and virtual reality, modeling/visualization of abstract concepts and complex systems

- Lloyd Stoolman (Medical School) created an online virtual microscope which allows students to study hundreds of high-resolution, true-color microscopic images 24 hours a day. Just as they would in the lab, users can scan a sample at low magnification, then enlarge any part of the image two- to four-fold without losing detail. Interactive questions allow students to check their knowledge as they review course material. (http://141.214.5.223/virtualheme/)
- Traianos Gagos (LS&A, Classical Studies) and Kathryn Beam (Special Collections Library) combined expertise to create a lively, interactive guided tour of the evolution of biblical text and images over the course of 16 centuries.

- Dennis Pollard (LS&A, Romance: Spanish) and Alain Martinossi (LS&A Romance: French) use a variety of web-based exercises and activities to create virtual day trips on which students research, plan, and take virtual trips to various locations in Spain and France.
- Tilly Peters (School of Dentistry) used Macromedia Director to design and develop interactive learning modules for anterior esthetic restoration, which can be distributed to students as CD-ROMs.
- Joseph Trumpey (School of Art and Design) created Eco-Explorers: An ecosystem comparison project in which internet technology (the Web and digital photos) brings the field into the classroom. (http://www.lib.umich.edu/ummu/costarica/)
- San Duanmu (LS&A, Linguistics) created Sounds of English to teach the mechanical basis for creating the sounds of American English and the International Phonetic Alphabet through game-like exercises with relevant feedback. Users see how to produce each sound by examining movies, animations, and text.
- Santhadevi Jeyabalan (LS&A, Biology) developed CyberFly, a virtual electronic genetics lab in which students breed various strains of flies to determine patterns of genetic inheritance. While breeding multiple generations, students keep track of different traits, eventually mapping which chromosomes in the fly were responsible for the observed traits. Unlike some commercially available genetics simulations, CyberFly doesn't simplify the experiment or coach students on correct answers. They do the work and analyze their results just as they would in the lab, getting a feel for what it's like to do scientific work, but not getting mired in details.
- Sabine Gabaron (LS&A, Romance: French) excerpted original cultural videos to create multimedia applications with which students of varying degrees of language proficiency explore aspects of French culture in order to identify and discuss differences between life in France and the United States.
- Faculty in LS&A's Department of Mathematics teach students in sophomore multivariable calculus (Math 215) to use a computer algebra system (MAPLE) to visualize the analysis and geometry of curves, surfaces, and vector fields in higher dimensions.
- Diana Baker (School of Medicine) produced instructional materials based on genetic counseling sessions and used them to demonstrate via evidence-based instruction the application to different learning domains in genetic counseling skills.
- Tom Gest (School of Medicine) developed multimedia assets (digital video clips and animations) to enhance the courseware and promote active learning of gross anatomy.
- Brent Gillespie (College of Engineering) developed an interactive simulation tool for hands-on instruction in dynamics for an undergraduate mechanical engineering course. With the simulation, students can touch and interact with virtual objects through the haptic interface.
- Tilly Peters (School of Dentistry) developed Scaffolding Dental Education: From Glass Ionomer to Composite Resin. Development of a Virtual Tooth Library: Interactive Preclinical Manual.
- Brett Seabury (School of Social Work) is developing a "you finish the story" application that simulates an interview with a person in crisis and allows students to make choices about treatment or responses in case studies of clients.

- Nancy Mason and Lynda S. Welage, (College of Pharmacy) designed Case Based Computer-Assisted Instruction to Enhance Clinical Skills to enhance graduate pharmacy courses in patient monitoring. The application gives students an opportunity to learn and practice specific clinical skills in a realistic context prior to applying them with real patients.
- Michael Gordon (Business School) developed Interactive Web Simulation of Business Processes in which students engage in a virtual internship at a simulated company on the Web.
- Kathleen Faller (School of Social Work) developed an online child welfare training program. (http://www.ssw.umich.edu/icwtp)
- John Cherry (LS&A, Classical Studies) uses web-based resources to lead students in introductory ancient civilization courses on virtual tours of ancient archeological sites.
- Perry Samson (Engineering: Atmospheric, Oceanic & Space Sciences) offers students one of two options: to create a website on Our Changing Atmosphere through a report on the chemicals we are adding to the atmospheric environment and their impact; *or* to meet four times during the semester with a Research Assistant for a 15-minute videotaped interview during which the students will be asked to answer a weather related question using weather maps from the CD-ROM and to explain to the interviewer what they did to answer the question and why.
- LS&A's Kelsey Museum of Archeology has a variety of online exhibitions, collections, and databases available to students and the public. (http://www.umich.edu/~kelsydb/)
- The College of Pharmacy developed the Michigan Applied Pharmacokinetics Computer Assisted Learning Modules, which provide students with animations illustrating how drugs are transported across membranes. Simulations of the liver, kidney and blood allow students to change various conditions and see how drug levels fluctuate. The modules are posted online, making them available to students and practicing pharmacists any time.
- Sherri Smith (School of Art and Design) oversaw the New Genre Media Initiative in Art and Design. Students and faculty now use computers and other technology to help design and produce jewelry, sculpture, furniture, fiber art, and other works. The technologies allow artists to explore three-dimensional design in ways that previously were difficult and time-consuming, if not impossible. A jewelry maker, for example, can reshape a virtual version of an object many times before using real materials. Mixed media artists use the precision of laser modeling technology, and electronic media artists teach students to use sensing devices to make interactive artworks.
- The Medical School has developed The Visible Human: complete, anatomically detailed, 3-D representations of both male and female human bodies. Video, audio, text, and graphics are linked to the 3-D representation in order to explain and expand upon the images. (http://vishuman30.us.itd.umich.edu/)
- The Medical Center and the Department of Emergency Medicine are developing a highly realistic virtual reality medical theater that immerses interns in the chaotic, fatigue-laden environment of a real-life emergency room and tests their ability to rapidly develop a plan of action and carry it out. The Virtual Reality-Enhanced Medical Readiness Trainer integrates advanced technologies like

human patient simulators, immersive virtual reality CAVE systems, next generation Internet technology, and virtual video conferencing in the context of distributed and shared virtual environments to train emergency personnel in a variety of common as well as extreme situations. (http://www-vrl.umich.edu/mrt/team.html)

- Philip Cascade (Medical School) developed an interactive CD-ROM program to enhance the teaching of cardiac imaging.

Research as Part of Teaching

Access to and retrieval of information and resources, analysis, and examination

Facilitate access to scholarly and instructional resources (web access to variety of resources, media delivered on CD-ROM, digital libraries and information resources); Improved access to course materials (digital reserves, online publishing, End Note, library on the web, citations); Share information and resources with classmates (shared workspaces, showcase student work): Analysis of primary data (ISR data sets, GIS Data, remote sensing data, satellite data), graphic display of quantitative data

- Deborah Ball (School of Education) created SLATE, a multimedia collection of materials, designed as a learning tool for beginning and experienced teachers. The collection contains a set of 27 thirty-minute-long digitized video clips of third-grade class sessions, transcripts, examples of children's written work, teachers' logs, and written reflections and other artifacts gathered from the classroom. Search capabilities facilitate analysis and tracking.
- Frances McSparran (LS&A, English Language and Literature) lead the development of Middle English Compendium, which was designed to offer easy access to and interconnectivity between three major Middle English electronic resources: an electronic version of the Middle English Dictionary, a HyperBibliography of Middle English prose and verse, based on the MED bibliographies, and an associated network of electronic resources. (http://ets.umdl.umich.edu/m/mec/)
- Jonathan Maybaum (Medical School) created an animated illustration of ligand-receptor interactions.
- Joanne Pohl (School of Nursing) built a computerized patient database with variables from an educational practice, evaluation, and research point of view. Nursing students can enter, summarize, reflect on, and learn from the data.
- In the Department of Mathematics (LS&A), students in sophomore differential equations (Math 216) learn to use a general purpose mathematical software package (MATLAB) as a tool for analyzing and solving problems in dynamical systems.
- Sheryl Pearson, (LS&A Humanities, UM-Dearborn) provides online literature with streaming audio that is free for all CourseTools discussions.
- Claire A. Michelini (School of Nursing) provides online library reserves and threaded discussions to share experiences and expectations of students during clinical rotations.

- Mark Clague (School of Music) created an online "listening library" and journaling to improve accessibility to materials and community-building among students.
- Gary Beckman and Kathryn Babayan (LS&A, Near Eastern Studies) created The Middle East Online to present web-based readings, illustrations, and supplementary materials for NES 100, a large enrollment introductory course.
- Margaretha Sudarsih (LS&A, Asian Languages and Cultures: Indonesian) created an image database of original photographs from Indonesia so that students would be able to explore the culture of everyday life in Indonesia without ever leaving the United States.
- In partnership with the Schomburg Center for Research in Black Culture, C. Olivia Frost and her students (School of Information) developed an online virtual exhibit of a photographic portfolio depicting the Harlem Renaissance (www.si.umich.edu/CHICO/Harlem/). A similar exhibit depicts the African Presence in the Americas: 1492–1992. (http://www.si.umich.edu/CHICO/Schomburg/)
- Hilda Tao (LS&A, Asian Languages and Cultures: Chinese) created Getting Around in Chinese CD-ROMs from originally filmed video skits so that students could purchase their own CD-ROM copies of the DVD video materials the instructors uses in class.
- David Crawford (School of Music) developed a Renaissance Liturgical Imprints: A Census.
- John Swales (LS&A, English Language Institute) leads MICASE, a motion media database of Academic Spoken English from which students and faculty can search and explore specific examples of Academic Spoken English.

Original research, projects, and other creative work

Student research projects, student research that becomes part of a database or future course/research resource portfolios, design/modeling; virtual events/creative events (installations, art galleries, interactive art events)

- Sue Alcock (LS&A, Classical Studies) had students in a first-year seminar explore a variety of worlds (the ancient Mediterranean, mortuary archaeology, museums, and museum display) and then create online exhibits descriptions and analyses, which are still available on the Kelsey Museum website.
- Philip Myer (LS&A, Biology and Museum of Zoology) created the Animal Diversity Web which allows students to explore information about animals from all over the globe. In addition, students conduct their own research and write species accounts adding sounds and images when available. These reports are published on the Web, expanding the database with each new semester's work.
- Eric Rabkin (LS&A, English Language and Literatures) created the Genre Evolution Database (http://www.umich.edu/~genreevo) in which English students use a web-based database to collect data on readings. They test the hypothesis that cultural creations evolve in the same way as biological organisms, that is, as complex adaptive systems that succeed or fail according to their fitness to their environment and, by their existence and success, modify their environment.

- Margaret Hedstrom, David Wallace and students (School of Information) collaborated with students and archival staff at the University of Fort Hare in South Africa to develop an online exhibit including key materials from the archives of the African National Congress.
- Melissa Gross (Kinesiology) (http://www.umich.edu/~mvs330) provides students with the opportunity to explore first hand the internal and external forces acting on the body during human movement by assigning team projects to compare the biomechanics of various motions. Students learn to analyze human motion by capturing movements of their choice on videotape and then transferring the images to digital format on the computer. Once in digital format, the students conduct biomechanical analyses to determine the essential elements of human motor performance.
- Eric Rabkin (LS&A, English Language and Literatures) offers a course in Multimedia Explorations in the Humanities in which students work in groups creating and/or augmenting web-based resources for the study of a humanities topic of their choice. All students study in the field of their chosen group, learn modern information technology, and use that technology to produce materials that become part of ongoing resources for use by themselves and others.
- Nicholas and Margaret Steneck (LS&A, History of the University of Michigan) have students research topics, write scripts, shoot supporting video, and digitize relevant images/audio clips to create a final class project — a forty minute, broadcast-quality documentary on the history of the University.
- Joanne Leonard (Art & Design) offers a course on the Photo Essay in which students learn digital storytelling with Premier in order to create presentations of stills and text with voiceovers.
- Brian Coppola (LS&A, Chemistry) divides students in the honor's section Chemistry 215H/216H into Structured Study Group in which each 2-3 student group is responsible for a web-based presentation of a step or two in a chemical sequence. Students learn and animate the mechanism of their step(s), correlate the author's NMR spectral-structural assignments, elaborate on the experimental procedure, identify a literature source for information about the mechanism, and respond to some leading questions. At the end of the term, this work is published in three formats (at this website, as a printed text, as a CD-ROM archive of the website). Students in the following semesters use previous semesters' projects as a resource on which to build their own ideas about presentation of chemistry ideas in a web-based environment. (http://www.umich.edu/~chemh215/)
- Armand Lauffer (School of Social Work) oversaw the creation of Project StaR, a website linking the resources of academia to those of the American Jewish community. Students were responsible for collecting and creating links to websites relevant to social service programs in Jewish communities, determining criteria for including sites and deciding how to describe them. The resulting resource provides access to information on Jewish communities and organizations, culture and religion, learning resources, and history.
- David Porter (LS&A, English Language and Literatures) incorporated a research aspect into undergraduate English courses by building "Eighteenth-Century England: a Web-based research project site for undergraduates."

Communication and Collaboration

Communication/ Discussion (asynchronous/ synchronous)

Virtual office hours, live discussions with multiple locations, guest participation (experts, informants, and native speakers), freedom of expression and anonymity (sensitive discussions w/out identity), threaded discussions VIA chat rooms, Moos & Muds, e-mail, bulletin boards, online discussion, web-casting, video conferencing

- Larry Gant, Sherrie Kossoudji, Rich Tolman, et al. (School of Social Work) developed the NILE Project: New Interactive Learning Experiences, which uses interactive teleconference, real audio, and the Internet to reach distance learners. (http://www.ssw.umich.edu/fot/)
- Claire A Michelini (School of Nursing), created online library reserves and threaded discussions for students to share experiences and expectations during clinical rotations.
- Sabine Gabaron (LS&A, Romance Languages: French), Alain Martinossi (LS&A, Romance Languages: French) and Hartmut Rastalsky (LS&A, Germanic Languages) have students practice language skills in local chat discussions.
- Sherri Kossoudji (School of Social Work) holds online office hours and posts all questions and answers for students in the course to reexamine outside of office hours.
- Robin Queen (LS&A, Linguistics) holds virtual office hours in a chat room.
- Adelwisa Weller (LS&A, Asian Languages and Cultures: Tagalog) has her American students e-mail with students in Manila to encourage authentic language use and more realistic examination of Philippine culture.
- Johanna Eriksson (LS&A, Germanic Languages: Swedish) has her students conference with students in Sweden, as they each explore aspects of ecology and society in the different cultures.
- Clare McAlister (LS&A, Romance Languages: Business Spanish), Margaretha Sudarsih (LS&A, Asian Languages and Cultures: Indonesian), Raquel Gonzalez (LS&A, Romance Languages: Spanish), Bruce Spencer (LS&A, Germanic Languages), and Holly Cashman (LS&A, Romance Languages: Spanish) facilitated synchronous discussion with Conferencing on the Web (COW). Their students conducted chats, role plays, debates, and other discussions—all in the target languages.

Collaborative work

Peer editing, peer review for content, student group projects, collaboration between students at multiple institutions, collaboration between faculty and students in multiple locations; submission, editing, and publishing of multi-author documents

- Instructors in the Sweetland Writing Center use a variety of tools, including CourseTools to develop "writing communities" online. Working collaboratively fosters in the students a sense of writing as a social, communal process and promotes richer in-class discussion.

- The Online Writing and Leaning (OWL) program is peer tutoring conducted by upper-level undergraduates who have completed the Peer Tutoring Program. OWL was conceived as a supplement to the face-to-face program, reaching out to students not located in the central campus area or otherwise unable to come in (perhaps due to child care or job responsibilities); it has also attracted traffic from all over the world.
- Brenda Imber (LS&A, English Language Institute), Sabine Gabaron (LS&A, Romance Languages: French), and Adelwisa Weller (LS&A, Asian Languages and Cultures: Tagalog) use CommonSpace to facilitate peer editing and process writing in their language courses.
- Raquel Gonzalez (LS&A, Romance Languages: Spanish) used both the ECB Notebook and CourseTools to encourage students to create their own cross-section collaborative Spanish newsletter.
- Nancy Kerner (LS&A, Chemistry) facilitates the CoLABnet (Collaborative Laboratories through Networked Computers) project which redesigned the first-year chemistry course to give students a more realistic feel for how science is done. Students work in teams, with each team using different samples and/or conditions. CoLABnet software collects, pools and summarizes qualitative and quantitative data from teams in all sections of the course in to a class data bank. Students then think about, manipulate, and discuss data, as well as make predictions about untested samples, answer "what-if" questions, and explore relationships among variables.
- The Business School's e-Lab involves students, practitioners, and scholars from a variety of disciplines in work on various problems involving business-to-business, business-to-consumer, and intra-organizational interactions mediated by information technology.
- The Digital Music Ensemble encourages students to participate in interdisciplinary exploration and has fostered collaborations with sculptors, dancers, engineers, and computer graphic and video artists.

Multi-institutional/Cross-national instruction

Teaching collaboratively with other universities, sharing classes to take advantage of unique faculty strengths or rare resources

- Deba Dutta (School of Engineering: Mechanical Engineering and the Program in Manufacturing) facilitates multi-national course in Global Product Realization between the universities in Ann Arbor, Delft in the Netherlands, and Seoul, South Korea. The real-time course utilizes videoconferencing and interactive web applications. Students are divided into six person project teams with two members from each site and work on the design and fabrication of a product for the Global Market.
- Larry Root (School of Social Work and ILIR, Ann Arbor) and Bruce Pietrykowski (CASL, Dearborn) direct the UAW-Ford University Program in which undergraduate courses from UM–Dearborn are being taught to UAW-Ford employees in pilot plants around the country. The courses are delivered via CD-ROM, streaming video, and the Internet, with infrastructure and student support provided through the Ann Arbor campus.

- Faculty in LS&A's Geological Sciences Department , in the School of Engineering's Atmospheric, Oceanic, and Space Sciences Department, and in the School of Natural Resources and Environment team-teach an interdisciplinary course sequence in Global Change — a novel approach in undergraduate science and social science education. In three interdisciplinary, team-taught courses the topic of Global Change from physical and human perspectives are examined, and case studies are used to explore conditions for sustainability. The courses are aimed at first- and second-year students who want to understand the historical and modern aspects of Global Change. (http://www.sprl.umich.edu/GCL/)
- Anne Ruggles Gere (School of Education) oversees the Technology Assisted Teacher Education (TATE) Project, which links three groups who previously had few opportunities to share their knowledge: secondary school teachers of English, graduate students preparing to teach college literature courses, and undergraduates preparing to teach at the secondary level. Interactive video, Internet resources, E-mail and other technologies are incorporated into teacher education and professional development. A teacher in Southfield, Michigan "invites" prospective teachers into her classroom to see how she conducts a reading-writing workshop. Teachers in California offer a virtual tour of Angel Island and use the tour to explain how their geographic location influences the way they teach Fae Mynne Ng's novel, *Bone*, which portrays life in San Francisco's Chinatown.
- Derrick Cogburn (School of Information) teaches a course on globalization, which is a distance-learning collaborative effort involving students at U-M, American University in Washington, D.C., and the University of the Witwatersrand, and the University of Fort Hare in South Africa. The class meets for lecture and presentations each week via the Internet. (http://www.si.umich.edu/Classes/607/)
- The Community-Based International Learning Program (School of Nursing) is a joint project of the Beijing Medical University Department of Nursing and the U-M School of Nursing, designed to build long-term relationships that contribute to the on-going use of the most up-to-date, culturally relevant knowledge in effective health care.
- Maurita Holland and students (School of Information) conducted cultural heritage preservation institutes for Native American youth and their teachers at the Navajo Nation and the Upper Peninsula. The institutes focus on how digital technology can be used to help Native American communities share their heritage with each other and with broader audiences by using the World Wide Web. (http://www.si.umich.edu/CHPI/')
- Nine School of Social Work faculty members (Charles Garvin, Michael S. Spencer, Larry Gant, Ron Astor, Lorraine Gutierrez, Robert M. Ortega, Oscar Barbarin, Barry Checkoway, Janet Finn) are involved Global Program on Youth PIs which uses technology to facilitate communication between School of Social Work researchers, policy makers, and agency workers. (http://www.ssw.umich.edu/youth)

Accessibility to previously inaccessible materials for students and faculty with disabilities/ adaptive technologies

- The University of Michigan's Adaptive Technologies Site is jointly sponsored by the Shapiro Undergraduate Library and the Office of Services for Students with Disabilities. Located in the Shapiro Undergraduate Library, the site is an ergo-assistive work-study environment with variety of specialized hardware and software to accommodate the information technology needs of physically, visually, learning, and ergonomically impaired individuals. (http://www.umich.edu/~sites/info/atcs/) and (http://www.rit.edu/~easi/).