TEACHING GLOBAL DISRUPTION AND INFORMATION TECHNOLOGY ONLINE

Bill Tomlinson, University of California, Irvine
Donald J. Patterson, Westmont College
Bonnie Nardi, University of California, Irvine

Computer science has always dealt with limits. Developing effective algorithms that compensate for limited memory, limited computational power, and limited bandwidth are central to the discipline. Over time technology has gradually raised these limits (e.g., Moore's Law) to such a degree that computing now competes for large-scale access to the electrical grid, oil, and other energy resources, as well as rare-earth minerals. These resources were not traditionally thought of as limits for computing. On the other hand, sectors of society that have always worked with limited physical resources such as agriculture, logistics, and utilities have now embraced computing as a means of operating more efficiently and now consume even more intensively than before. To capture these new intersections between computing and resource usage, the term *Computing within LIMITS* was coined.

In 2015, a group of researchers, including the three authors of this article, organized the first LIMITS conference, which provided a venue for bringing together scholars from many different subfields to foster "discussion on the impact of present or future ecological, material, energetic, and/or societal limits on computing." (http://www.limits2015.org/) These ongoing discussions provide the intellectual context for the university course described here.

In 2014, the authors proposed an undergraduate course to the UC system motivated by the perspectives, concerns, and knowledge fundamental to the Computing within LIMITS community (e.g., [1,2]). Through a competitive process, the University of California Office of the President's (UCOP) Innovative Learning Technologies Initiative (ILTI) awarded us a grant to prototype and run the course. Our goal was to enable students to learn a range of concepts—about information technology, global sustainability, and various limiting factors on industrial civilization—that are foundational to the thinking that underlies the LIMITS perspective. UCOP's goal was primarily to respond to California Governor Jerry Brown's initiative to explore online teaching as a potential source of increased efficiency in higher education. The course was titled "ICS 5: Global Disruption and Information Technology."

ICS 5 was one of the first online courses to be offered across the nine undergraduate campuses of the University of California system. The course has been offered three times to date: Winter 2015, Fall 2015, and Spring 2016. Here we describe the course, and our experiences teaching it, in an effort to help others offer similar content to students at various educational levels.

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RELATION TO PREVIOUS EFFORTS

The role of sustainability in computing education has been a growing topic of interest to the computing community (e.g., [3]). Stephen Sterling argues that "sustainability does not simply require an 'add-on' to existing structures and curricula, but implies a change of fundamental epistemology in our culture and hence also in our educational thinking and practice" [4]. Teaching LIMITS involves embracing the notion of fundamentally rethinking certain tenets of industrial civilization.

A course at the KTH Royal Institute of Technology in Stockholm, addressing a range of topics at the juncture of IT, sustainability, and related topics [5], is perhaps the most similar existing course to ICS 5. Its instructors offer a framework designed to conceptualize courses in this domain. The KTH course, for graduate students, was targeted at a more experienced student community than the undergraduates enrolled in ICS 5. One of the challenges we faced was that most of our students took the course to satisfy a science and technology GE requirement, and typically were not science or technology majors. We see our work on ICS 5 as complementary to the KTH course, by offering a more introductory level of exposure to the core content.

PEDAGOGICAL CONTENT

The syllabus included the following summary: "This course seeks to understand how sociotechnical systems (that is, collections of people and information technologies) may support a transition to a sustainable civilization that allows for human needs and wants to be met in the face of global change." There were three primary curricular goals. The first was to educate students about the science of global change. The second was to educate students about the sociotechnical approach to technology design, which the three instructors have pursued throughout their careers. The third was to engage students in understanding and critiquing their own values and the processes by which such values may be brought to bear in the creation of sociotechnical solutions to global change.

Each week, we offered several five- to 15-minute videos, as well as several readings. The course covered a range of weekly themes, including: Peak Week, where we discussed peak oil, peak information, and various other global turning points; Wicked Week, where we discussed the complexity of this suite of problems; and Hope Week, where we presented a variety of successful projects that communities and governments have taken on that have resulted in meaningful positive changes.

One of the challenges of teaching

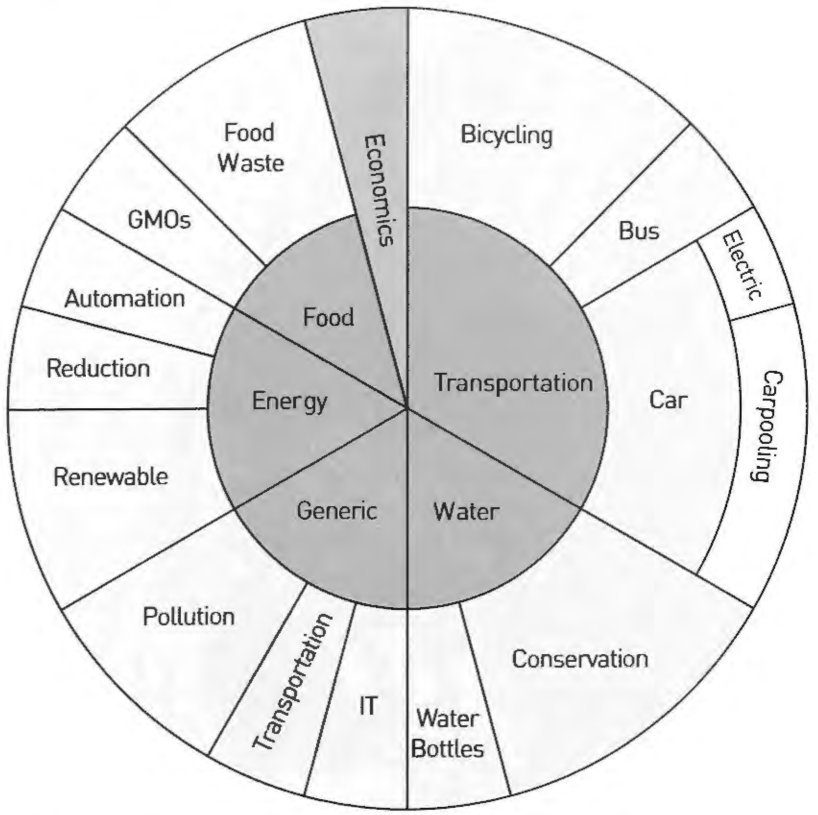

Figure 1. A hierarchical categorization of student final projects by topic.

and responding to sustainability concerns in general, and those in this course in particular, is how to avoid communicating despair or hopelessness. The problems that sustainability entails are overwhelming, bnt we felt that creating enthusiasm for tackling them and helpful ways of thinking about them was an important point of offering the course. As a result, we structured the course as a descent into the problems in the early weeks, and then an ascent to solutions, ideas for solutions, and case studies of successes in the later weeks.

We occasionally took students on virtual field trips—videos we shot on location at venues such as UCI's eWaste recycling center, an aquaponics facility near UC Santa Cruz, and an urban garden in Los Angeles. We included numerous video guest lectures with scholars from around the world whom we solicited specifically for this course.

To further reinforce the activist stance we wanted students to develop, we required each person to undertake a capstone activity for the course. In the first two offerings, students were asked to create videos about a topic of interest to them that related to the concepts of the course. In the third offering, students were asked to write a 2,000-word paper. Student projects covered a wide array of topics, from pointed critiques of UCI's sprinkler systems to humorous satires of iPhones (as we will discuss).

A key premise of the course is that while technology may be able to address some aspects of sustainability, the core problem lies with the nature of current industrialized society. Many students come to the course with a solutionist mindset: Technology is good for fixing things and making things better, and therefore the way forward is to find the right things to fix and then create some innovative technology to do so. While there are some elements of the course where we point to technological solutions to concrete problems, the broader remit is to help students understand that a problematic cultural perspective is at the root of many of the issues facing industrial civilization. Throughout the course, we seek to help students think about these cultural and political issues, and when thinking about using technology to solve problems, we focus largely on how IT can help shift sociopolitical perspectives in beneficial ways.

STUDENT POPULATION AND EXPERIENCE

In the first offering of the course, we had 95 students from 28 different majors. The vast majority were students at UCI, with four students from other campuses. In the second offering, we had 149 students—a 56 percent increase—all but one from UCI, across 38 majors. The third offering included 220 students from 40 majors. Again, the vast majority were from UCI.

This diversity of students, and the fact that many of them did not have technical backgrounds, made it critical for us to teach the course in ways that would be accessible to students without technical experience. We tried to leverage the diversity of the student body to enrich the course, encouraging students to draw on their personal experiences and expertise from their majors when replying to discussion boards and creating their final projects.

Student evaluations of the course were generally positive, from 7.14 to 8.04 across the three offerings (on a scale of 1–9). UCI course evaluations do not include questions tailored to capturing the broad intellectual impact of the course. While KTH has a question in which students rated how "meaningful" a course was for them, UCI's evaluations do not include a similar question. The sheer existence of a question about how meaningful a course has been demonstrates a commitment to a particular kind of educational outcome, and one that is more aligned with sustainability in general. Nevertheless, in terms of "encouraging students to think," which is perhaps closest to being meaningful, the course scored an 8.40/9, 8.01/9, and 6.80/9 in the three offerings of the ICS 5 to date, indicating that it was fairly effective at encouraging students to think.

Nevertheless, despite our efforts, we found that many students struggled to grasp the core premise of LIMITS. This premise runs counter to prevailing mental models that most residents in industrialized civilizations adhere to—that growth is inherently good, that technology can and should support that growth, and that more technology, is, on balance, hetter.

This conundrum is an ever-present challenge in our efforts to offer this course in the spirit of the LIMITS community. The notion of offering this course online, partly about information technology, at a major research university, in which all students are essentially required to participate in myriad industrial infrastructures, flies in the face of the core perspective we hope to present. Requiring high-quality Internet access, computers with the latest software and protocols supported, 10 weeks of dedicated time to complete the course, and enrollment in a UC undergraduate program all play into and reinforce a ubiquitous growth perspective that is embedded in current U.S. higher education. This implicitly undermines our premise that scarcity, contraction, and simplicity may well be the hallmarks of our future. As a result, it is not surprising the students had a hard time navigating both of these worlds simultaneously and tended to fall back to the cultural norms that require growth.

Nevertheless, we had an impact on some of our students and hope the impact extended further. Surprisingly, many students told us they had never thought about sustainability at all before the course. (Students may sign up, as noted, to fulfill at GE requirement, or to take an online course to ease their busy schedules.) In addition, in an email exchange after the course was over, one of the students in the second offering wrote to the instructor, "I think you'd be happy to know that I'm working at [a global environmental information company]. How I ended up here was largely inspired by what I took away from ICS 5." This is the kind of impact we have sought to have.

STUDENT PROJECTS

Analyzing students' final projects gave us insight into the thinking and approaches that the students brought to the class.

In the first two offerings of the course, we required students to engage with the particulars of the UC system. From the final project description: "This project involves envisioning and/or discovering a way that IT may help provide for a particular aspect of human well-being in a sustainable way, and documenting plans for enacting that intervention on or around one or more UC campuses." While this description biased students toward a pro-technology or more-technology perspective, it was a considered choice: In an assigned project from the offline version of ICS 5 some years earlier, in which the instructor had given students the option of thinking about "negatechnologies" [6] or other ways of consciously removing technological systems, students seemed largely baffled by the premise and process by which one might remove technological systems. Therefore, as this was an introductory-level course, we chose to focus on the interventionist approach. In future offerings, we want to find a way to strike a balance between the two approaches.

In Figure 1 we grouped the projects from the first offering of the course into hierarchical categories. The high-level categories included Food, Water, Transportation, Economics, and Generic. The Generic category referred to papers that made non-specific appeals to sustainability in general ("We need a way to bring energy-awareness to the masses") and reflected the ability of the student authors to mimic the dominant narratives in sustainability or repeat research findings that they had read, while stopping short of critical engagement with the results or actual innovation. Fortunately, this category was only a small proportion of the papers.

CONCLUSION

Computing within LIMITS is critically important to the future of the computing discipline, and potentially a powerful transformative force in the world more broadly. We see teaching LIMITS in general, and this online course in particular, as a pathway to this greater engagement.

With more than 186,000 undergraduates drawn from the world's best and brightest students, the University of California is an important global institution of higher learning. Enabling as many UC undergraduates as possible to take this course could help reduce the impact of global disruption from resource competition by connecting the computing discipline to the hroader discourse on sustainability. We hope it is a model and inspiration for other efforts at universities around the world. We believe our experiences can make a small contribution to this greater effort.

ACKNOWLEDGMENTS

This material is based in part on work supported by the NSF under Grant No. CCF-1442749. We thank the many faculty, staff, and students across the UC system for their efforts in bringing various stages of the course into existence, in particular Rebecca Black and Clara Caldeira. We would like to thank the UCI Center for Engaged Instruction for the Celebration of Teaching Instructional Technology Innovation Award, which we received for this course in 2014.

ENDNOTES

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Bill Tomlinson is a professor of informatics at UC Irvine. His research interests include ICT for sustainability, computing within limits, computational agroecology, crowdsourcing, and computer-supported learning.
→ wmt@uci.edu

Donald J. Patterson is an associate professor in the Math and Computer Science Department at Westmont College in Santa Barbara, California. His research lies at the interface of ubiquitous computing, artificial intelligence, and human-computer interaction.
→ dpatterson@westmont.edu

Bonnie Nardi is a professor in the Department of Informatics at UC Irvine. She is interested in social theory, political economy, collapse informatics, and a few fun things like video games. She is the author, with Hamid Ekbia, of *Heteromation and Other Stories of Computing and Capitalism* (MIT Press, 2017).
→ nardi@uci.edu

DOI: 10.1145/3003818