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Special Topic on Sustainable HCI Education

Design Without a Future

Citizen Interaction Design

Bonnie Nardi, Bill Tomlinson, and Donald J. Patterson, Special Topic Editors

SUSTAINABLE HCI EDUCATION

Over the past several years, there has been a movement afoot within the academic community to develop new ways to teach sustainable HCI. These efforts have taken a step away from incremental or individualistic forms of sustainability, which focus on issues such as efficiency, persuasive technologies, and behavior change. Instead, they are addressing societal and systemic forms of sustainability, with an awareness of the need for both the mitigation of and adaptation to climate change, global limits, and the idea that the growth characteristic to industrial civilization for several centuries may not be infinite.

In this Special Topic, we present three papers that address different aspects of this domain. In "At Odds with a Worldview—Teaching Limits at a Technical University," Daniel Pargman and Elina Eriksson describe a sustainability course where many of the ideas are directly at odds with the core premises of the graduate-level technical degree program in which it is embedded. The course actively seeks to challenge students' worldview. They discuss how they handled the unconventional demands of such a course. >>>>

SPECIAL TOPIC

Bill Tomlinson, Donald Patterson, and Bonnie Nardi contribute "Teaching Global Disruption and Information Technology Online," which is similar in spirit to Pargman and Eriksson's work, but aimed at an undergraduate audience. As with Pargman and Eriksson's graduate course, "Global Disruption" seeks to challenge students' default ways of understanding the world. Rather than primarily engaging students at a professional level, the course incorporates many topics within students' educational and personal contexts, with the goal of helping them see some of the problems that are embedded in the nature of industrialized society.

In "Computing Education for Sustainability—What Gives Me Hope?", Sam Mann goes one step further, speaking from within a longstanding engagement with the computing discipline to suggest that perhaps computing may not be well suited to delivering a sustainable future.

Taken together, these three articles present a new way to think about the relationship between sustainable HCI and education: At the very least, students should be challenged to confront the difficulties embedded in the ways they live in the world, and they might also consider that computing, in its present form, may be too deeply embedded in those difficulties to be a productive leverage point for an intervention.

Enjoy!

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AT ODDS WITH A WORLDVIEW—TEACHING LIMITS AT A TECHNICAL UNIVERSITY

Daniel Pargman and Elina Eriksson, KTH Royal Institute of Technology

IMAGE BY GREENTEA LATTE / SHUTTERSTOCK.COM

This article takes as its starting point the staggering challenges humanity is now facing and will continue to face during the remainder of the 21st century. During the past century, our civilization has experienced an explosion in ingenuity, knowledge, and creativity, but it has also shaped the world in such a way that some researchers suggest we have left the Holocene and are now living in a new geological era called the Anthropocene. Ours is a finite planet, and human-induced (anthropogenic) developments have pushed the earth system beyond safe boundaries when it comes to biochemical flows, climate change, and biosphere integrity [1]. Perhaps even more alarming, we are still in the dark in terms of understanding those limits (e.g., the concentration of aerosols in the atmosphere, chemical pollution in the form of heavy metals, toxic substances, endocrine disruptors), while the output from our industrial system continues to pollute and alter the atmosphere, the biosphere, and the oceans. We are simultaneously reaching limits to what we can harvest from the Earth in terms of non-renewable resources like minerals and oil [2]. These large-scale developments are capping the possibilities for what can be developed and built in the future, including computational systems and devices. Computing itself will be bounded by the limits and the challenges and changes. Since they will affect all of us, we believe tbey should be addressed in *Interactions* and by the HCI and interaction design community in general.

We teach an introductory course in sustainability and ICT (information and communication technology) to first-year media technology engineering master's students at KTH Royal Institute of Technology in Stockholm. We are planning to teach the fifth cycle (the course debuted in 2012) in parallel with the launch of a new master's level track, Sustainable Information Society. Many of our students major in HCI; they will do research or work as practitioners of usability and user experience for decades to come. In this article, we will first elaborate on two approaches to addressing and teaching engineering (computing) students about the environmental and other challenges presented above. We call these approaches *vanilla* and *strong* sustainability. We will reflect on our experiences in meeting these challenges head on and teaching our students about sustainability and computing from a perspective that emphasizes strong sustainability.

VANILLA VERSUS STRONG SUSTAINABILITY

In planning, teaching, and evaluating our course on sustainability and ICT, and having taken courses on sustainability ourselves, we are aware of the various stances a teacher can choose when communicating and teaching the topic [3]. In many cases, especially in engineering education, the foremost stance is to present problems in such a way that they become possible to solve through picking low-hanging fruit in the form of energy efficiency, incremental technological innovations, or by applying human ingenuity. If those solutions seem inadequate, another option is the omnipresent catch-all of hoping for technological breakthroughs (the hydrogen economy, electric cars and smart grids, breeder reactors, carbon capture and storage, geoengineering, space migration, and so on). *All proposed solutions are habitually placed within an imagined future social, political, and economic system that will allow us to continue to live as we do today and where the developmental trajectory*

does not differ significantly from what we have experienced during the past 100 years. This imagined future ties into the dominant narrative that we live at the best of times and that economic and technological progress has solved, and will continue to solve, any problems we are and will be encountering.

We have previously defined this stance as *vanilla sustainability* [4], a perspective in which mitigation strategies are employed to avoid calamity and where the problems might be severe, but will somehow still always be manageable. It could be that this perspective is especially attractive to students and professionals in the information and computing sciences because it both defines the problem of sustainability as 1) manageable and relatively easy to solve and 2) as a problem that *someone else* will solve (someone working with transportation, energy, pollution, planning, policy—anyone but me!). Nothing could be further from the truth. Living in a world of absolute limits will affect us all, and we all have to pitch in, both in our professional roles and as private citizens.

In between "This is easy" (vanilla sustainability) and "This is too hard," we carve out a stance we choose to call *strong sustainability*. Strong sustainability does not shy away from taking seriously predicaments such as climate change, planetary boundaries, future scarcity of nonrenewable resources (fossil energy, minerals), and the consequent challenges this scarcity will pose for our economic system. This perspective is tough to take on, and for some, provocative in challenging the sustainability (or indeed the possibility) of everyone striving to take on Western lifestyles, or even for Westerners to maintain their current lifestyles.

In earlier writing we have called this stance *doomsday sustainability* [4], not because it implies we are approaching the end of the world, but because it implies the end of the world *as we know it*—our social and economic systems will have to change in countless major ways to address the insurmountable predicaments in front of ns. This stance to teaching sustainability embraces uncertainty and addresses issues that might be unavoidable, such as climate change and resource depletion, including their global and long-term consequences. This perspective, in turn, requires adaptation strategies and presents visions of the future that to some extent can be perceived as bleak and challenging, and where computing might not play a central role.

TEACHING LIMITS

In university courses there is often a gap between the syllabus and the actual course. Since vanilla sustainability is the norm at our university and in our society, we believe that most syllabi tend toward bland, uncontroversial formulations either because these formulations represent an accurate description of the (bland) course contents, or because it makes for fewer problems for teachers, like us, who complement or fill their courses up with more radical course contents. There are thus several levels we can use to describe the goals we have with teaching our course.

The most basic level is to ascertain that the course taught corresponds, or corresponds well enough, to the course that was promised. Our experience is that students, at least at an engineering university, seldom complain about the actual ("political" dimensions of) lecture contents, the choice of literature, and so on, but that administrative gaffes of various kinds can become the topic of complaints (e.g., a problem with the attendance list, a last-minute change in the instructions for a seminar, delays in grading). Also, we have found it exceedingly rare tbat students compare the course given with the course promised (as described by the syllabus) and complain about discrepancies. Assuring that the course runs smoothly and fulfills the most basic requirements is important, but our goals with the course are definitely higher than just delivering what has been promised in official documents.

The next level is to move our students to care, at least a little, about sustainability and otber issues we raise in the course. We have written about the challenge of engaging media and computer science students in what many of them (at least before the course) regard as "a topic of little relevance to their future careers" [4]. We have concluded that it is crucial to find ways to connect and bridge the distance between students' perceptions of their own profession and sustainability as a topic.

We do, however, believe that it is *easier* to move students with course content that takes strong rather than vanilla sustainability as the starting point, and by not avoiding discussions of difficult topics. Such discussions can bridge the gap between our current affluent Western lifestyles and the nagging feeling that our way of life is, in fact, patently unsustainable (probably within the lifespans of our 20-something students and especially so if scaled up globally). Such discussions also acknowledge that sustainability is *the* challenge of the 21st century, and what we mean by affecting our students can be handily summed up in a hypothetical student's sudden realization that "...oh my god, does that mean that *I personally* have to...?". This realization constitutes a direct challenge to many students' worldviews. As an example, and despite the fact that the course hardly touches on the topic of food, it seems this is an area where many feel that they can make a difference. We know that several students felt the course was the straw that broke the camel's back to make them go vegetarian. It should be said, though, that we don't know if this is a temporary decision from which they later retreat (say, three or six months after the course is over). Some students experience a wake-up call like this as a mixed blessing:

The revelations have made me more anxious about life and our future. It's good stuff but I would probably be more happy without it. Not knowing is bliss. (2015 student answer to a questionnaire that was distributed a third of the way into the course)

Yet another level of describing our goals for teaching the course is to go beyond the individual here and now. We want our course and the lessons and perspectives we offer our students to be something they internalize and carry with them during the remainder of their education, as well as into their private and professional lives. By affecting our students' worldviews, we as teachers challenge the business-as-usual worldview of our technical university through our students' own actions. We notice it when some students take our lessons to heart, and their other teachers complain to us that students' questioning attitudes about sustainability constitute a "distraction" in their courses. One student complained about the cognitive dissonance of taking hard environmental limits into account while simultaneously taking a course at the Stockholm School of Economics, where she worked on a task to increase the revenue of an airline company by optimizing the pricing of seats. It is of course harder to know if the alternative worldview we present has an impact in their lives after they leave the university, but there are encouraging signs that it might.

Ultimately, the goal for us is to teach students a perspective that they will not only practice in their own lives, but that will also support them to act as change agents, affecting and persuading others to work toward the endeavor of building a more sustainable society in both their private and professional lives. We do, however, have to prepare them for this effort, since the strong sustainability perspective will be at odds with other, less forceful sustainability perspectives. In the best of all possible worlds, we would like them to act as insiders who are part of the dominant culture, but who at the same time try to change the system they are part of from within. In sum, we want them to balance between a complacent reasonableness and G.B. Shaw's "Maxims for Revolutionists":

The reasonable [person] *adapts himself to the world: The unreasonable one persists in trying to adapt the world to himself. Therefore all progress depends on the unreasonable* [person].

CHALLENGING A WORLDVIEW

We have outlined a stance called strong sustainability, which we have chosen to adopt in our first-year master's level course about ICT and sustainability. By adopting this stance, we have also chosen to make life a little more difficult for both ourselves and our students. Many of our students tell us that they felt alarmed and unnerved in particular during the beginning of the course, when lectures focus on the predicaments described in the introduction. However, we believe it is important to dare to confront the hard facts of the state of the world and discuss them. In that way we avoid slipping into the socially constructed denial so often sought when we are faced with disturbing issues [5].

Strong sustainability and its implications for the future professional and private lives of our students constitute a direct challenge to most students' worldviews. This also constitutes a challenge to the predominant ethos at a technical university in general, and a school of computing science and communication in particular. So how has this gone down with the students? We have to say we are surprised how ready our students have been to listen to what we have to say. But we have experienced the whole gamut of reactions, from polite rejection to students craving to hear more, including a request to continue the seminars after the course had ended.

While planning the course and giving the course for the first time, we were very nervous. What if our students wouldn't accept the perspective we were presenting? What if our experiences would come to mimic those of high school chemistry teacher Dan Allen:

Upon hearing my "pessimistic" news, many of my students immediately begin to formulate ideas to "save us." With optimism as their default setting... they want to see it as a solvable problem... They seek to find some technological way out of this energy jam. Lifestyle change is simply not a thinkable option [6].

To counter any and all possible objections, we had massive amounts of additional information for all eventualities at hand during the first cycle of the course. Afterward, we realized that the students were much more receptive to the ideas than we had anticipated. We later asked ourselves where the students' openness came from, and our hypothesis nowadays is that it comes from living through the 2008 European debt crisis. That event and its aftermath now constitute a major part of any 20-something university student's life, and what is considered normal to their parents' generation (e.g., economic growth, employment, and continued prosperity) is not necessarily something that young adults born in the 1990s will assume.

These students are the ones we entrust with the task of creating the sustainable society that we have failed to create. Adopting a vanilla sustainability stance could never have been an option for us since we believe that computing and HCI will be severely affected by coming changes, and that we are as responsible for addressing the problems as any other discipline. Perhaps we are even more responsible than many disciplines, since computing has become such an important part of the infrastructure in society at large.

We argue that HCI researchers and practitioners are well equipped to be change agents due to the baked-in multidisciplinarity of HCI and the bridging capacity it can encapsulate. We are already in between—in between technology and use, between system and human, between the boardroom and the shop floor. We can also be between sustainability and development, bringing the ideas of a more sustainable society into the development of technology.

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TEACHING GLOBAL DISRUPTION AND INFORMATION TECHNOLOGY ONLINE

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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.

IMAGE BY MOPIC / SHUTTERSTOCK.COM

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

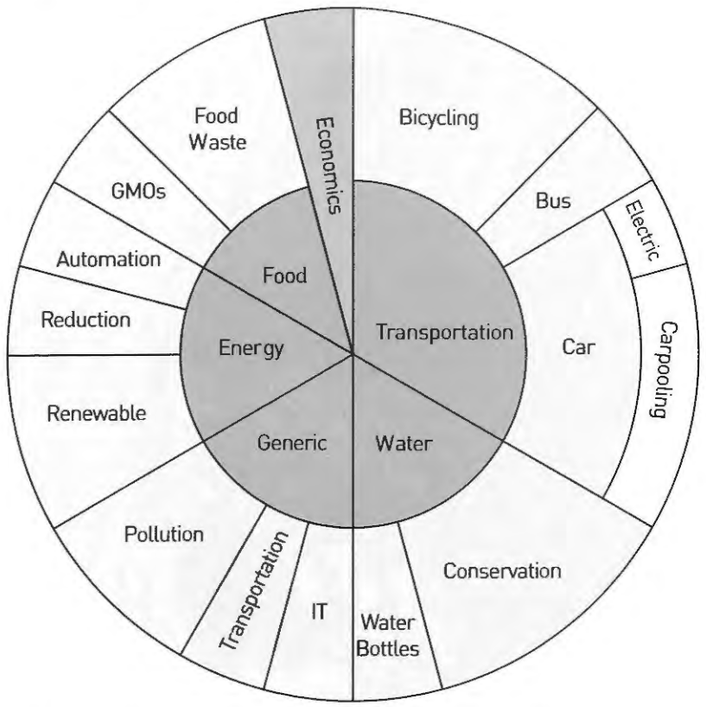

Figure 1. A hierarchical categorization of student final projects by topic.

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, better.

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 broader 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.

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IMAGE BY ANNA GRIGORIEVA

COMPUTING EDUCATION FOR SUSTAINABILITY—WHAT GIVES ME HOPE?

Samuel Mann, Otago Polytechnic

After more than 20 years in computing, I doubted our field's desire or ability to drive change. So I changed direction. Formerly a professor in IT, I am now a professor of sustainable practice in a post-discipline department specializing in professional practice.

My work centers around the notion of the *sustainable practitioner* and the *sustainable lens*. You can think of education as being about the development of your lens—how you see the world, your values, and your mindset. The early bits of life and education are about developing your personal lens, mixing your values with opportunities to practice increasingly advanced sets of skills. Then higher education is about turning that into a professional lens. The focus of my work is in making sure that the personal and professional lenses are also sustainable lenses.

In 2011, I began a radio show and podcast called "Sustainable Lens: Resilience on Radio" (sustainablelens.org). On that show we have had conversations with more than 270 people from many different disciplines who are actively working for a sustainable future. In our talks, we try to find out what motivates our guests and what it means to see the world from a sustainable perspective—

through their particular sustainable lens. The archive on Sustainable Lens provides wisdom, optimism, challenges being faced, and things that can be done. The show presents a positive, forward-looking vision. Our guests are people who are working—in a variety of scales and contexts—for a sustainable future. What can we learn from them to help us scale that up to the socio-ecological transformation we really need? (Throughout this article, I point to particular Sustainable Lens interviews as noted by their names in parentheses.)

For me, the most important thing is identifying and helping the disciplines that have the greatest societal leverage. That is, the disciplines where the handprint—the potential to do good—is massively greater than the negative impact, the footprint. Education, computing, and in particular HCI are disciplines with very high societal leverage, so that is where I have focused my career.

Computing has the promise of being such a leverage discipline. Its handprint is massively greater than its footprint. Don't get me wrong. Its footprint is huge, too; if we just consider climate change (and we shouldn't, as sustainability is much broader than that, but energy and carbon are useful proxies), ICT contributes about 2 percent of anthropogenic greenhouse gas emissions (Chris Preist, Barath Raghavan). This is about the same as the aviation industry. It's a huge footprint, and we need to do everything we can to reduce this burden on the planet. But computing's potential handprint is bigger—much bigger. Skip Laitner estimates that our society runs on about 14 percent energy efficiency: "We are wasting most of what we produce" (Skip Laitner). While not the only solution—we need to consume less, too—a chunk of the gain Laitner describes can come only from ICT-enabled systems improvements, perhaps as much as 30 to 40 percent.

Education can similarly be considered a leverage discipline. Our service—our potential to do good—is vastly greater than our negative impact. This is why education for sustainability is fundamental to the global Sustainable Development Goals. Most, if not all, tertiary organizations have begun to address the operational aspects of sustainability. But few have addressed education for sustainability in a holistic, multidisciplinary, and systematic manner. The notions of the sustainable practitioner and the sustainable lens can provide a vehicle for this project.

In 2007, Otago Polytechnic adopted as a core strategic objective the statement that "every graduate may think and act as a sustainable practitioner." The statement has been revised over the years but still holds, as illustrated in the opening paragraph of Otago Polytechnic's Annual Report:

Guiding our students through a formative time in their lifelong learning journeys is a special privilege. At Otago Polytechnic, they engage in an experiential learning process and emerge as capable, work-ready, future-focused and sustainable practitioners [1].

Otago Polytechnic's sustainability journey is explored in *The Green Graduate* [2] and *The Simple Pledge* [3]. Rather than specifying in advance a predetermined set of behaviors to describe a sustainable practitioner (either generically or for each discipline), instead we aim to take students on a journey toward identifying what it means for them to think and act as sustainable practitioners. After nearly 10 years, 93 percent of graduates agreed with the statement, "My learning experience developed my understanding of social, environmental, and economic sustainability" (2013). In the Graduate Employer Survey (2012 data), 94 percent of employers rated "Demonstrate an understanding of social, environmental, and economic sustainability" as a criteria for employment as very high, high, or moderate, and 87 percent agreed that Otago Polytechuic graduates demonstrated this attribute. The international benchmark AUSSE survey (2013) asked respondents to rate the learning experience on a number of dimensions, including "[the learning experience] contributes to living in a sustainable way." OP respondents were considerably more agreeable tbau the benchmark (58 percent agree, compared with 35 percent for both national and international benchmark groups).

Both computing and education can clearly have a big effect on sustainability. Therefore the potential for combining them as Computing Education for Sustainability (CEfS) was appealing. While I had been doing sustainability through computing before 2007, in that year my colleagues and I began a series of papers on computing education for sustainability. We first linked sustainability and computing, quoting United Nations Secretary General Ban Ki-Moon, who argued that "information and communications technologies (ICT) are crucial in spurring development, dignity, and peace." He urged us to "turn the digital divide into digital opportunity" and said that ICT should be promoted "in fighting poverty, illiteracy, and disease; in protecting the environment; and in empowering women and girls." We responded, "As computing professionals, we need to examine what role we see computing professionals playing in that future. As computing educators charged with creating those computing professionals, we are doubly responsible, as we also have put in place the system to get us there" [4]. In another paper we took up this challenge and described the drivers for CEfS [5]. We explored options for including sustainability in computing qualifications. We looked for, but couldn't find, whole degrees in sustainable computing—iudeed whole courses were similarly elusive. Our preferred approach was one of "critical inquiry and integration throughout the curriculum in ways that are both incremental and transformative" [4].

That paper concluded with a suggested agenda for developing CEfS. After further workshopping at a national conference, an agenda was developed by the New Zealand National Advisory Committee on Computing Qualifications (NACCQ). NACCQ (then its successor organization CITRENZ) added sustainable practice to all computing qualifications. Most recently, all sub-degree computing qualifications were completely rewritten in a government-mandated review. All such New Zealand computing qualifications now include explicit requirements for sustainable practitioners in the graduate profile outcomes. On an international level, a series of workshops at ACM's ITiCSE conference brought CEfS to the attention of international computing educators (Michael Goldweber). The eventual outcome of this was the recognition of the sustainable practitioner in the ACM CS2013 Core Curriculum as a Core Tier 1: "Identify ways to be a sustainable practitioner."

So, has this been a success? Have we made it? Unfortunately, no.

If we take the example of HCI, seminal papers such as Blevis's "Sustainable Interaction Design" (Eli Blevis) prompted a flurry of research in sustainable HCI. However, as Brynjarsdottir et al. [6] found, much of this research is weak and focuses on a limited framing of sustainability and human behavior, or, as Eric Meyers and Lisa Nathan [7] described, is research with an "impoverished" focus.

In describing computing as a potential leverage discipline earlier, I positioned computing as having strength in driving computing-supported efficiencies. But now I believe this is not just ineffective; in fact, this focus is doing us harm. To be clear, computing does need to address its own footprint, which will require education. And it does need to maximize its handprint, which will also require education. But so far we have been ineffective at addressing the handprint, and for the most part have gotten stuck on energy efficiency, with limited effectiveness and quite possibly even doing sustainability a disservice (Bran Knowles).

Computing for sustainability cannot be just about efficiency gains. The problem transcends carbon and energy. How can computing help reverse biodiversity loss? Or massive global inequities? Or even local problems, such as why the logs are transported on the road instead of on the adjacent train track? Nor is it just about the environment—the systems in question are as much social as they are biophysical. As a society we have to learn to live in a complex world of interdependent systems with high uncertainties and multiple legitimate interests. These complex and evolving systems require a new way of thinking about risk, uncertainty, ambiguity, and ignorance [8]. They require that we think simultaneously of drivers and impacts of our actions across scales and barriers of space, time, culture, species, and disciplinary boundaries. It means we need to switch from a focus on outcomes to one of process. Ethics and sustainability are rarely as simple as choosing between an obvious good and an obvious bad. The world is beset with wicked problems, but, as Andy Read describes, "the wickedness of problems is no excuse for standing by" (Andy Read). We need to be thinking about every decision and every action contributing to a system operating under ethical principles. Sustainability provides a framework for expanding ethical reasoning to a complex world.

So what gives me hope? The previous paragraph does—and the fact tbat some computing researchers are beginning to recognize this as the next step (Six Silberman). Batya Friedman and Lisa Nathan's multi-lifespan information systems have really looked at how we might start to address intergenerational equity (Batya Friedman). I'm excited by work that focuses on community engagement, not as a means for behavior change, but for the sake of an empowered community: Steve Benford's trajectories and uncomfortable interactions (Steve Benford), the University of Lancaster's work on Tiree (Maria Angela Ferrario), Rob Comber's empowering communities (Rob Comber), and David Green's participatory documentary making (David Green). This research is supporting community to create sustainable futures beyond the behavior-change-intervention-via-new-product paradigm.

So now, rather than being critical of computing, I'm instead working to demonstrate positive alternatives. There are a number of computing people on Sustainable Lens working on positive solutions (http://sustainablelens.org/?cat=66), but if you look for only one, I suggest going beyond computing and listening to Richard Latham and Jennifer McIvor of Wishbone Design Studio (Latham and McIvor). If we could do computing for sustainability like they do business, the world would be a better place.

I began a career in computing to make a difference. I would like to think that I have made that difference. I am now making a different difference, directly supporting the professional practice of people who want to be considered sustainable practitioners. So here's the question I would like every computing educator to ask themselves: How is my work contributing to a restorative socio-ecological transformation at scale?

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ENDNOTES

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