Teaching Pervasive Computing in Liberal Arts Colleges

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In this article, we reflect on the critical role of liberal arts education in fostering creative, collaborative, and ethical innovators for pervasive computing. We discuss why liberal arts education is important as a foundation for advanced studies and leadership in ubiquitous computing, and we share our experiences teaching pervasive computing in liberal arts colleges.

The notion of ubiquitous computing has inspired researchers and innovators for more than two decades, offering the promise of augmenting our everyday environment through seamless integration of interconnected computational devices. Thus, technology becomes invisible yet pervasive—accessible anytime and anywhere. Invisible technology, however, has visible impacts on individuals, communities, and society. It presents exciting opportunities to improve work, leisure, healthcare, and education, but also has a widespread potential for misuse, particularly threatening individual privacy and security.[1] Considering both the promise and challenges of pervasive computing, we argue here that liberal arts colleges have an important role in preparing interdisciplinary leaders, innovators, and practitioners who will contribute to the development of ubiquitous computing systems with positive societal impacts.

WHAT IS LIBERAL ARTS EDUCATION?

Liberal arts education aims to "liberate students from narrow ways of thinking,"[2] preparing them not for a particular job or vocation but rather to become lifelong learners who are well-equipped to ethically participate and lead in an ever-changing world.[3] Liberal arts colleges focus on undergraduate education, fostering skills such as critical thinking, logical argumentation, problem solving, and communication.[4] Students typically study topics from a broad range of disciplines, gaining insight into human nature, the characteristics of various communities and societies, human creativity and artistic expression, as well as a fundamental understanding of scientific and computational methods. The values of interdisciplinary collaboration and of pursuing truth

through ethical and data-driven inquiry[5] are instilled intentionally, not only through academic teaching but also through extracurricular activities and community service.

WHY LIBERAL ARTS EDUCATION IS IMPORTANT FOR PERVASIVE COMPUTING

There are several key reasons why liberal arts education is relevant for the emerging field of pervasive computing.

First, interdisciplinary collaborations are necessary for developing successful ubiquitous computing systems. While technical expertise is critical for development and deployment, so are artistic and design sensibilities, as well as an understanding of human abilities and needs. In the words of Steve Jobs,[6] "technology alone is not enough—it's technology married with liberal arts, married with the humanities, that yields us the results that make our heart sing." Liberal arts colleges strive to produce graduates that not only value interdisciplinary collaborations but are also equipped to thrive within interdisciplinary teams and environments.

Second, students with a liberal arts background, who are educated to become informed global citizens, tend to be motivated to apply novel technologies to solve important human problems, helping people "live happier and healthier lives."[6] Having spent time studying the characteristics and ways of thinking of individuals and of different cultures, such students are well-positioned to work on ubiquitous computing projects that focus on human needs, while aiming to generate positive societal impact.

Finally, liberal arts studies provide students with a lens through which to assess *unseen* societal and cultural implications (both positive and negative) of pervasive technology. In the past year, we have read an increasing number of reports about the ramifications of shifting human decision-making to automated processes.[7] Ethical framings of pervasive computing will be critical to avoid past mistakes as our research community pushes to weave technology more intricately into the human experience. Yet detecting and articulating the effects of new ubiquitous technologies *before they are introduced* is difficult (and unlikely) without a background steeped in the social sciences or humanities. Through courses in and collaboration with these disciplines, students are more likely to develop reflective habits of mind as a core component of their education, allowing them to shift into roles of not just inventors but also *ethical* creators.

TEACHING PERVASIVE COMPUTING IN LIBERAL ARTS COLLEGES

Here we describe two facets of teaching pervasive computing topics in liberal arts settings: integrating ethics and critical thinking into technical courses, and engaging students in creating novel ubiquitous computing projects while working in multidisciplinary teams.

Integrating Ethics and Critical Thinking into Computing Education

A key component of the liberal arts education is that broader perspectives are not experienced *in addition to* technical courses but are integrated *into* technical courses. The introductory computer science course at Bucknell University includes modules that pair with existing curricula to provoke reflection on the integration of automated decision-makers into our everyday lives. In the "Ethical Engine" module,[8] students practice object-oriented programming while coding a driverless car that chooses between saving its inhabitants or saving pedestrians on the street (http://moralmachine.mit.edu). The system detects various physical and socioeconomic characteristics of people, and students must wrestle with the implications of incorporating those factors in their algorithms. Similarly, in the "Ethical Hiring" module, students write a simple hiring algorithm that sifts through GPAs of applicants and decides who to automatically reject.[9] Students not only gain competency in programming structures but are challenged to think about

questions such as “What does it mean to design a fair algorithm?” and “What systemic advantages/disadvantages are my algorithms likely to amplify?”

Likewise, at Wellesley College, the introductory course “Computing for the Socio-Techno Web” includes an educational activity that challenges and equips students to think critically about the truthfulness of news propagated in social media.[10] This activity utilizes TwitterTrails, a visual online tool for analyzing Twitter claims, events, and memes.[11] This tool provides interactive visualizations that help users to answer questions about the spread, impact, and truthfulness of Twitter stories. Using the tool and an accompanying response and reflection form, students are guided through an evidence-based inquiry, examining the characteristic of a Twitter story and learning to identify indicators that impact credibility.

Project-Based Courses

At Wellesley, a project-based course on tangible user interfaces emphasizes design thinking while exposing students to the theory and practice of tangible and ubiquitous computing. The course provides students with both the technical skills required for building tangible and ubiquitous human–computer interfaces, and the conceptual foundations required for critical evaluation of their strengths and limitations. It is structured around a semester-long team project in which students from different backgrounds work together designing and constructing tangible and ubiquitous user interfaces of their own creation. Students are encouraged to pursue ambitious projects that have positive societal impacts, and to present them not only to their peers at Wellesley but also at research conferences.

For example, a recent student project focused on improving women’s health. Crimson Wave[12] (see Figure 1) is a personal tangible user interface that consists of a smart mirror and a wearable armband developed by class of ’18 undergraduates Margaret Flemmings, Rachel Pak, and Shanzay Kazmi. The armband was designed to be worn during the night and to measure basal body temperature, which fluctuates during different stages of a menstrual cycle. Using these nightly measurements, the mirror generates and displays personalized health information for its user. Motivated by the limitations of existing applications for tracking women’s health, this team of students sought to invent a novel method of keeping track of one’s health and integrating one’s menstrual information seamlessly into daily life. The students presented their prototypes at this year’s ACM Conference on Tangible Embedded and Embodied Interaction. This research engaged the conference community in an important discussion on how to better design more inclusive personal ubiquitous computing systems.

Figure 1. Wellesley College class of ’18 undergraduate students Margaret Flemmings, Rachel Pak, and Shanzay Kazmi present Crimson Wave, a personal ubiquitous computing system for tracking menstrual health.

Another recent project demonstrating societal impact focused on enhancing social-emotional communication for children on the autism spectrum. EmotiBubbles (see Figure 2) is a soft tangible user interface designed to promote social-emotional learning and communication through a multisensory and playful user experience. The interface consists of a plush pillow with soft bubbles that represent different emotions. Children can squeeze one or more bubbles that reflect their emotions at the moment and receive visual and haptic feedback depending on the emotions they select. Class of '18 students Katy Ma and Pooja Diwakar were inspired by social-emotional learning methodologies and affective computing research, aiming to blur the lines between assistive technology and play.

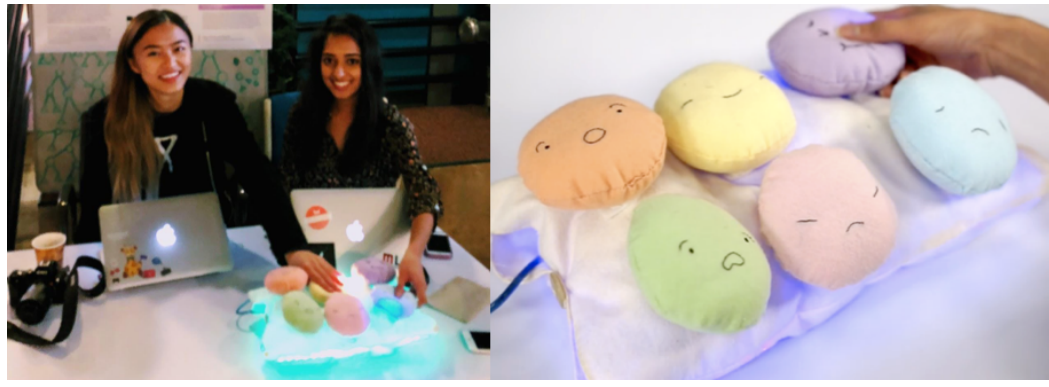

Figure 2. Wellesley College class of '18 undergraduate students Katy Ma and Pooja Diwakar present EmotiBubbles, a soft tangible user interface for promoting social-emotional learning and communication.

At Bucknell, a project-based human-computer interaction course encourages experimentation with emerging technology such as natural language interaction, 3D user interfaces, affective computing, and virtual reality. In this course, students engage in six small projects that each shift the design process to various input technologies and design goals (for example, *Design for Tension, Design for Wellbeing, Design for Fun*). The goal of the course is to not only to provide students with a flexible, human-centered design process but also to equip them with the skills to communicate and engage the public with their designs.[13]

For example, in the "Design for Tension" course module, undergraduate students Anushikha Sharm (Class of '19), Sierra Magnotta (class of '18), Mitch Petrimoulx (class of '18), and Uttam Kumuran (class of '18) built Alice (see Figure 3), a Facebook chatbot designed to help people who may be dying to come to terms with their mortality.[14] As users talk to Alice, the chatbot guides them to reflect on a series of topics such as regrets about the past, concerns about family they may be leaving behind, and even their beliefs about life after death. Although the student group shared a common computer science background, they also integrated unique perspectives from majors and minors in linguistics and women and gender studies that allowed them to design a compelling prototype that approaches a difficult topic.

A final example of engaging students in creating novel ubiquitous computing projects while working in multidisciplinary teams is the AffecText project. Motivated by the desire to improve understanding between people, students in the "Design for Wellbeing" module Anmol Singh (class of '18), Khai Nguyen (class of '18), Sean McDonough (class of '18), and Zach Brill (class of '19) set out to augment text-based messaging with emotional indicators. By applying a human-centered design process to affective computing technology, they built AffecText (see Figure 4), a messaging system that highlights messages with the predicted emotional state of the sender while also providing real-time feedback about the emotional state of the recipient.[15]

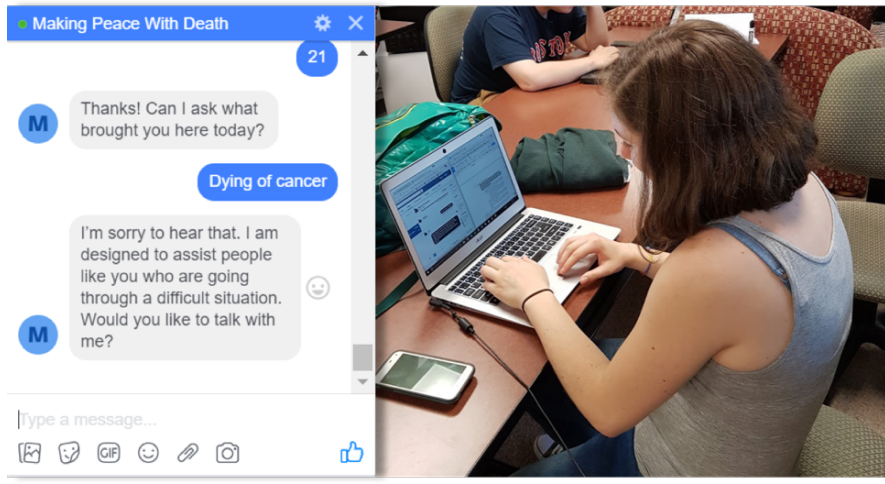

Figure 3. Bucknell University class of '18 undergraduate student Sierra Magnotta demos Alice, a chatbot designed to help people reflect on death.

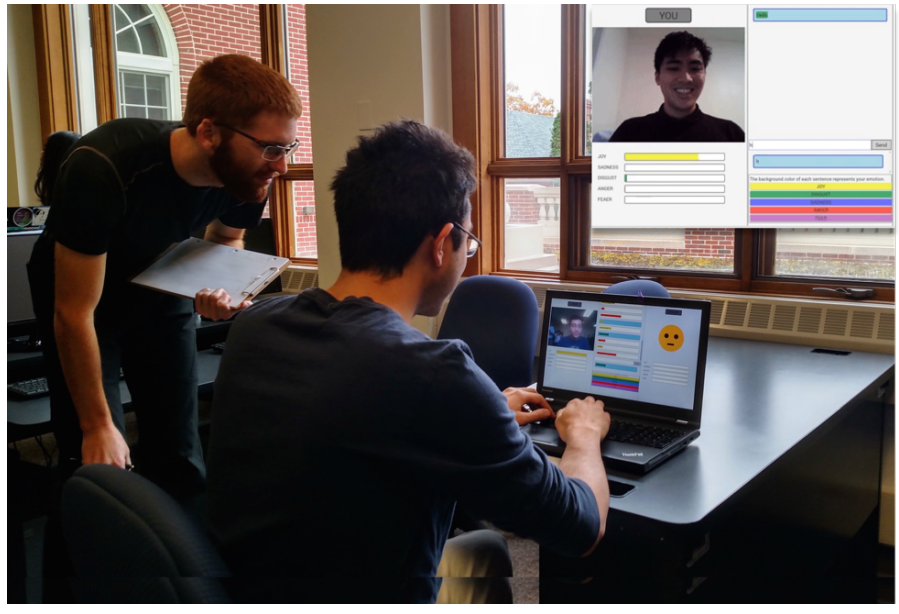

Figure 4. Bucknell University class of '18 undergraduate students Sean McDonough, Khai Nguyen, and Nick Simons test AffecText, a messaging system with affective indicators.

CONCLUSION

At a time when addressing pressing societal challenges and mitigating the negative impacts of computing is imperative,[16] liberal arts education of undergraduate students has a critical role—producing creative, collaborative, and ethical innovators. We are excited to share our own experiences teaching pervasive computing in liberal arts colleges with the hope of highlighting the value of a liberal arts education as a foundation for advanced studies, practice, and leadership in pervasive computing.

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