# An Approach to Integrating ICTD Projects into an Undergraduate Curriculum

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## ABSTRACT
Applying information and communication technologies to development (ICTD) is emerging as an interesting and motivating research area in computer science and engineering. It spans application areas from healthcare to transportation, and requires the use of computing skills from networking to user interface design. Addressing problems of developing regions and under-served communities lets students explore a different part of the ICT design space, leading to new implementation and research questions. ICTD is also an area that has the potential to excite students about the CSE field more generally, with its emphasis on enabling social benefits with technology, and is rich in possibilities for interesting student projects. In this paper we report on two offerings of a course at the University of Washington that introduce students to the field by way of 1) reading papers from literature in the area to gain exposure to this very different design mindset and 2) doing practical projects that engage students in engineering problems under unique design constraints. Our hope is that CSE educators may find our experiences useful in identifying an approach to integrating the field of ICTD into their curricula.

## Categories and Subject Descriptors
K.3.2. [**Computers and Education**]: Computer and Information Science Education – *Computer Science Education, Curriculum*.

## General Terms
Human Factors.

## Keywords
Capstone courses, service learning, socially-relevant projects, information and communication technologies for development

## 1. INTRODUCTION
Information and Communication Technologies for Development (ICTD) is emerging as an active area of research that showcases the connections between computing and the future of billions of citizens of our planet [4, 11]. The third IEEE/ACM sponsored conference on ICTD was held in April 2009 [14]. Projects currently exist in many computer science departments and emphasize the importance of collaboration with fields such as public health, education, agriculture, and business. Examples of projects in this area include flood detection, HIV/AIDS tracking, making crop prices available to farmers, microfinance, transportation coordination, and governance.

At the same time, research on attracting and retaining students suggests that educators should portray computing as a field through which one can contribute to the social good. ABET asks that by time of graduation, we provide our students with [1] “an ability to analyze the local and global impact of computing on individuals, organizations, and society.” Exposing students to ways that computing is having an impact in low-income regions and the developing world is one mechanism for making the field relevant and showing its power to impact the world positively.

In this paper, we describe our experiences teaching two offerings of a year-long undergraduate capstone design course on computing in the developing world, consisting of a one-quarter reading seminar followed by two quarters of design and implementation. We found that students were able to comprehend and be motivated by papers from the ICTD literature. Student groups implemented a variety of interesting ICTD-related projects that forced them to consider design challenges not encountered in their previous CSE courses. These challenges included creating low-cost technology solutions suitable for environments with intermittent power and low Internet connectivity, and designing interfaces appropriate for users who were illiterate or had a lack of comfort with technology.

## 2. RELATED WORK
There is a long history of interest in incorporating projects that have a positive impact on society into computing courses via service learning [5, 12, 18, 22]. Benefits of service learning include providing opportunities to build stronger relationships between the university and the community and to attract students to the field through the context of projects that have a positive impact on society. While not all projects in our courses went on to be directly deployed in the communities for which they were designed, we still saw students driven by a similar interest in using their technology skills to enable social benefits.

There has also been much recent interest in socially relevant computing (defined as the use of computation to solve problems of societal and interpersonal relevance) [7]. Examples include the incorporation of open-source humanitarian projects [17] and


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assistive technologies [6] into senior capstone design courses or as independent study projects. Layman et al. discuss the importance of designing individual assignments to demonstrate how computer science can be used to aid society or to have some practical value [15]. Socially relevant projects are seen as a good fit for the altruistic leanings of this generation of students [19].

Our course builds on the motivation and success of the work mentioned above in that it focuses on projects that have the potential to impact society in a positive way—in our case, in the context of low-income and developing regions. A few universities are beginning to integrate the topic of ICTD into their undergraduate curricula [8, 24] although most such courses are at the graduate level, are housed in departments other than computer science, or do not involve implementation projects.

# 3. OUR COURSE

All computer engineering majors (and many computer science majors) at the University of Washington take a one-quarter capstone design course. These courses are mandated by ABET and are offered on a variety of traditional topics, ranging from computer animation to embedded systems, and give students the opportunity to design and implement substantial group projects. In addition, students gain experience presenting their work and justifying their design decisions.

In the 2007–08 and 2008–09 academic years, a new capstone design experience on the topic of technology for low-income and developing regions was offered [26]. The traditional, one-quarter capstone course was expanded to include two preliminary quarters of background and discussion in the area of ICTD. The reason for doing this, is that unlike the case for the more traditional capstone topics, students had not had much previous exposure to ICTD topics except, possibly, in the popular press. Furthermore, it was felt that having more time to iterate with potential users and/or ICTD experts would provide a richer experience and make the point that technology, to be meaningfully applied, has to involve stakeholders in its design from the very beginning.

## 3.1 Reading Seminar

The first quarter took the form of a one-credit literature review, in which students familiarized themselves with some of the challenges faced by residents of low-income regions. The course met an hour each week, and a different application area or design constraint was discussed at each meeting. Sample topics include education[21], transportation[25], non-literate user interfaces[16], microfinance[20], healthcare[10], and agriculture[13]. Reading lists can be found on the course web pages [26]. Our approach was to bias the paper selection toward papers written by technologists working in ICTD so that the students could more easily relate to the experiences they read about.

## 3.2 Project Design and Implementation

For the second quarter, in a two-credit design studio class, students were asked to organize themselves into groups of 4 to 6 based on their common interests and asked to come up with design ideas and implementation plans. In 2007-08, there were six project groups, in 2008-09 there were four. Throughout the quarter, students were continually asked to present their design ideas to the class and outside experts for feedback. We asked representatives of local NGOs working in ICTD, engineers of major companies in the local area working on applications for emerging markets, and other UW faculty familiar with the field to listen to student presentation and press on their reasoning both in terms of application space and design decisions. Again, the objective was to provide a realistic team design experience where decisions must be rationalized and explained to a wider audience.

The final quarter followed the more traditional form of other 5-credit capstone courses, although the focus here was primarily on implementation rather than design and implementation. Throughout the last two quarters, student groups were frequently required to present their ideas to the class and to panels of experts in formal presentations, poster sessions, and written reports.

# 4. EXAMPLE PROJECTS

In this section, we describe three of the course projects in greater detail. Other student projects from our two offerings of the course covered a variety of areas and technologies: writing educational games that allow several students to share a single computer via cheap USB keyboards, creating an educational application for the OLPC (One Laptop Per Child) platform, helping community health workers in Tanzania manage patient care using cell phones, empowering women in Kenya via community radio, making agricultural outreach video presentations more interactive via technology, and building a device that permits the safe and efficient recharging of batteries.

## 4.1 Improving Transportation in Kyrgyzstan

The goal of the *bus ("star-bus") project was to provide reliable transportation information to bus riders in Kyrgyzstan via GPS tracking devices and text messages. Currently, buses in Kyrgyzstan have set routes but no set stops or schedules. Riders must wave down a bus when they see one and have no idea when a bus will arrive. This leads to wasted time, and money (if a more expensive taxi must be taken instead), and can be a safety issue for riders waiting alone at night when service is less frequent.

In many places in the developed world bus riders have access to real-time transit information via electronic signs posted at stations or via the web – which they may have access to from a personal web-enabled phone. Students with GPS-enabled phones with Internet access may even be accustomed to keeping track of the location of their friends possessing similar technology.

In designing a transportation information system for Kyrgyzstan, students were forced to work within the constraints of a dramatically different landscape. While cell phones are owned by over 70% of the population, less than 15% own a computer or use the Internet (compared to 85% Internet use in the US) [25].

Students took this knowledge of technology use patterns in Kyrgyzstan into account, and designed an information system that fit well with a method of communication seen as common and affordable – SMS (a.k.a. text messages). Students wrote a server that runs on a computer with intentionally minimal requirements – a cheap laptop connected to a cell phone (no Internet access was required by the server). In the designed system, riders send text messages to the server inquiring about the arrival of their bus. The server sends its response back to the rider via SMS.

For their project, students also devised a mechanism for collecting information about the location of buses. Students built a hardware prototype device containing a GPS module that could be installed on buses being tracked by the system. These *box devices would then relay their location information over SMS to the server. The *box was intentionally designed to have a non-threatening appearance, low power requirements, and minimal street value to discourage theft (instead of equipping buses with GPS-enabled phones). An SMS interface to the tracking devices was also developed so that administrators could access them remotely and drivers would not be required to interact with them extensively.

The project is an example of one that was posed to the class by a colleague from another department, who identified the problem after years of experience in Kyrgyzstan. At the end of the course, some students from the project joined forces with another project group that had developed a system for supporting SMS-based applications. The newly formed group continued iteration on the project and eventually visited Kyrgyzstan to deploy their system, resulting in a senior thesis and research publications.

## 4.2 Marketing Native Crafts

The Empowering Artists group teamed up with business students at Heritage University in rural Washington state to allow artisans in remote regions to sell their art to the world. The group at Heritage had connections with local Native Americans and, by way of students at other universities, with Huichol artisans in villages in remote parts of Mexico that were interested in marketing their work. Although web sites such as eBay allow the sale of items directly from artist to consumer, most artists in these communities did not have either sufficient access or facility with technology to make use of these options. In addition, they did not want to compete directly with mass-manufactured replicas or culturally irrelevant goods, instead expressing a desire to preserve and accurately portray their cultural skills and values.

In investigating a possible solution, the UW computing students collaborated with their partners at Heritage to understand the problem constraints. It was eye-opening for the computing students to encounter the levels of mistrust of technology and outsiders expressed by some of the artists. To address this problem, the students proposed using the university students as both art documenters and trusted transaction intermediaries who would access technology on their behalf. This human-computer solution allowed students to recognize that technology alone rarely provides the entire solution.

While university students in both locales had reasonable Internet connectivity and computer skills, the CSE students still needed to create an easy-to use web-based back end for uploading content and keeping track of inventory that could be available in (at least) English and Spanish. In addition, they created a front end website that presented goods for sale in a way that would be acceptable to a wide variety of artists. Throughout the process, students were made aware of cultural sensitivity. For example, when one CSE student suggested using a Yakama language word to brand the project, Heritage students explained that many Native American tribes, including Yakama, did not want their languages used by outsiders. When the CSE students suggested enhancing the web site to support commissioning of artwork, they learned how the majority of Huicholes produce art sporadically and rarely by request.

## 4.3 Radio Craiglist

The CellPost project (a.k.a. Radio Craigslist) created a low-cost mechanism for advertisement of goods and services, employment opportunities, community announcements, lectures, and healthcare information. Students were inspired by reading about the use of community radio in the AIR [23] project, where it gave women a voice in communities in Africa. They were interested in using low cost technology to bring services such as those available on Craigslist [9] to people in remote communities.

To address this problem they combined two relatively cheap and available technologies: cell phones and community radio. Users with cell phones would call a server to leave messages (such as an advertisement of an item for sale or a job opportunity) that they wanted broadcast. The server was responsible for determining a schedule for broadcasting messages and was connected to an FM transmitter to allow local broadcast over a range of several miles. For their project, students selected and assembled a functioning suite of hardware (FM transmitter, antenna, cell phone, and low-cost laptop) and created the server software.

The students found several software packages available to help them construct the system. Asterisk [3], an open source telephony engine, was used to connect a cell phone (for handling incoming calls) to the server via Bluetooth. Voice menus were created to guide users to place their messages in the correct category and to allow administrators to remove inappropriate content. The use of voice as the mechanism for placing ads allows the system to be used by illiterate users. Similarly, the broadcast of content in audio form to radios (a low cost technology that is easily shared) makes the system available to a wide range of users.

A web GUI was designed so that (if the server was connected to the Internet) a remote user could upload content such as audio books, farming lectures, or English lessons from anywhere in the world for broadcast on the local station. The success of a similar system VoiKiosk [2] makes the students' solution look promising for actual deployment.

# 5. LESSONS LEARNED

## 5.1 Success of Course Structure

Our year-long model for the course, (1) a reading seminar followed by (2) a design studio and then (3) an intensive implementation push, worked well and spread the project effort nicely across the three quarters. The papers in the reading seminar were accessible to undergraduates to the point that they were capable of both leading and summarizing the discussion each week. We believe that the reading seminar could stand on its own as a course that would be relatively easy for instructors at other institutions to implement. Individual papers from the seminar could also be used as interesting supplements to courses such as human-computer interaction, operating systems, or networking.

We expect that it would be difficult to do ICTD-related projects similar in scope to the ones our students accomplished in a single quarter or semester. In our experience, students need time both to absorb content from the reading seminar and to appreciate the unique design constraints of their projects. Furthermore, having ample opportunity to present their ideas to a range of practitioners was immensely educational and reinforced the design concepts presented in the classes. Our model of gearing up in level of commitment and intensity from quarter to quarter also seemed to work well. Several students dropped after the first quarter, and we did have a couple that joined in the last two quarters, but, given the small numbers, this did not pose a significant problem.

## 5.2 Resource-Constrained Design

Typical capstone course projects are in domains at least somewhat known to students (games, animated films, social networking, education, shopping, trip planning) and are meant to be used in a context they are familiar with (e.g., by students like themselves or professionals living in a city similar to their own). These projects require students to design a solution to the given problem within a set of constraints (time, skills of group, hardware or software needed), and students inevitably wrestle with difficulties such as dealing with poorly documented software, hardware that does not work as advertised, and all the challenges inherent to group work.

One of the benefits of having students do projects in the area of ICTD is that it exposes them to a set of design constraints that they are unlikely to have encountered in any previous CSE course. Design constraints our students had to consider included:

- **Very Low cost** – Cost obviously takes on a new meaning in scenarios where people live on less than $2 a day. Expensive computing devices are at risk of theft or can even put their owners in personal danger. The *appearance* of low cost can be equally important to the actual cost.
- **Low power** – Although students will probably be familiar with the idea of conserving power for environmental reasons or to extend portability of devices, they are not likely to have designed for an environment where power is intermittent or relatively expensive or both.
- **Low connectivity** – While cell phone coverage is becoming more and more available worldwide, Internet coverage is still far from universal, and continues to be expensive. We simply can not rely on partitioning of tasks between mobile devices and servers, for example.
- **User interface challenges** – Several of our student projects had to design user interfaces that would be accessible not only to people of different languages and cultures but also to those who were illiterate or who had a fear or distrust of technology. Cultural sensitivities add another dimension.
- **Ease of maintenance** – Solutions that are deployed in remote areas or that must be maintained by inexperienced users pose an extra challenge. Hardware and software should be robust to the elements and designing a system so that experts can access it remotely can be invaluable.

The fact that design in ICTD inherently relies on the use of low-cost technology can be a benefit when trying to secure resources for student projects. Wide coverage and growing access has led the cell phone to become a much-used computing platform in the developing world. While voice connections can still be expensive and of varying quality, SMS (text messages) has proved useful for many applications. Low cost laptops like the OLPC and the new generation of netbooks are also starting to be deployed and present an interesting design point between phones and full-featured laptops. Community Radio is another technology that provides low cost broadcast communication.

## 5.3 Impact on Students

Overall course evaluations have been very positive. On evaluations, several students mentioned the value of thinking in a new way ("Very different view to develop technology for developing regions", "Thinking outside the box is really good for all engineering disciplines"). Several students mentioned the real-world and altruistic nature of projects as appealing ("Gave students an opportunity to help people…", "I had been looking for a class like this for some time. There should be more classes that offer a focus for the technology instead of just the technology."). They also frequently spoke positively about the year long nature of the course ("For developing world capstones, definitely keep the leading two quarters of introduction and design. The insight gained from studying previous work was crucial to developing a relevant capstone project.").

Despite most course projects only being prototypes, we had several students continue work on their projects well into the summer or the following year. Several of these took on lives as research projects, often leading to publications or senior theses. In a few cases, funding was found to allow students to travel to the region for deployment or usability testing of their project. Several students from the course are planning to continue work in ICTD in graduate school, another accepted an ICTD-related internship.

# 6. ADVICE TO INSTRUCTORS

Although several of our projects evolved from existing connections with other researchers, we believe you would not need to be an expert in the field or to have such connections to teach an ICTD-inspired project course. Instructors can use the background provided in the reading seminar to provide a motivating context for projects in low resource environments both close to home and abroad. Here we give suggestions for instructors interested in teaching similar courses.

- **<u>Students need the background seminar</u> in order to understand the human side of project goals and the source of unique design constraints.**

  Although in our experience this background proved to be eye-opening and created excitement for the majority of students, not all students may appreciate the broader implications of technological solutions or be motivated by projects in ICTD.

- **Instructors <u>need</u> to provide greater <u>guidance in project selection</u>.**

  Excitement about the potential humanitarian impact of their solutions coupled with a lack of deep understanding of an unfamiliar context can lead students to be overly ambitious when selecting projects. In our experience, instructors need to be particularly careful to reign in elaborate plans students may first propose when working in this new area and ensure that projects include a reasonable technical component whose implementation can be achieved in the time available (including experiments and contingency plans).

- **Instructors may <u>need</u> to provide more <u>guidance during projects</u>.**

  We found that while some student projects were self-directed, others needed significantly more guidance along the way. We suspect that this could be due to students' lack of certainly when working in this unfamiliar area. Besides a lack of direct experience with the domain (healthcare, agriculture), geographic region (sub-Saharan Africa, Kyrgyzstan), or culture, they may also have more difficulty finding answers to questions than they might with projects where information is more readily found on the Internet or from a local pool of potential users.

- **Keep in mind that projects are <u>only prototypes</u>.**

  The overall goal of student projects should be to prototype a solution with these unique design constraints, and to gain some understanding of the domain. While it is useful to hold students to reasonable reality checks (e.g., constant Internet connectivity is expensive and unlikely to be available), at the same time, an instructor can allow some flexibility in meeting these design constraints for the purpose of proof-of-concept and validation of the project's core idea (e.g., students might build specialized hardware to allow for the exploration of a design space, while at the same time calculating that larger quantities could be produced much more cheaply or that less-costly, off-the-shelf options could be used). For projects that lived on beyond the course, re-engineering parts of the system was often required.

- **<u>Look locally</u> for possible projects**.

  You may find low-resource communities in urban or rural environments in close physical proximity that allow students to pursue projects similar to those they read about in the ICTD literature. Reading the ICTD literature will help students be sensitive to issues that apply locally as well. Physical proximity may also allow visiting the site – which proved invaluable in our experience. We also found it useful to explore project ideas posed by colleagues in other departments that had significantly more experience with the context (e.g., transportation in Kyrgyzstan).

- **Consider having students do projects that are <u>part of a larger effort</u>.**

  The HFOSS project [17] allows students to contribute to open-source humanitarian projects, several of which have roots in the developing world (e.g., OpenMRS, Sahana disaster-management system). Participating in projects like HFOSS where students develop modules for existing projects allows students to leverage resources of a larger development community and more easily deploy their solutions in the field. Developing applications for a platform like the OLPC can have similar benefits.

Overall, we found that the course topic of computing for low-income regions and the developing world inspired many successful projects, while being motivating and eye-opening for students. The course has been offered twice so far and will be offered again in the coming year. A video about the course has been created for use as a recruiting tool [27].

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