A Novel Interdisciplinary Course in Gerontechnology for Disseminating Computational Thinking

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Abstract - While specialized knowledge and skills are the hallmark of modern society, the size and complexity of contemporary problems often require cooperative effort to analyze and solve. Therefore, experiences with skills, methodologies, and tools for effective interdisciplinary collaboration and structured problem solving are vital for preparing students for future academic and professional success. Meanwhile, computational systems have permeated much of modern professional and personal life, making computational thinking an essential skill for members of modern society. However, formal training in these techniques is primarily limited to students within computer science, mathematics, management of information systems, and engineering.

At Iowa State University, we have designed and offered an experimental course to develop undergraduate students’ abilities for interdisciplinary teamwork and to disseminate computational thinking skills to a broader range of students. This novel course was jointly designed and instructed by faculty from the Computer Science Department, Gerontology Program, and Graphic Design Program to incorporate diverse faculty expertise and pedagogical approaches.

Students were required to interview real users to identify real-life problems, gather requirements, and assess candidate solutions, which necessitated communication both within the group and with technologically-disinclined users. In-class presentations and wiki-based project websites provided regular practice at disseminating domain expertise to larger interdisciplinary audiences. Workshops, group-based mentoring, peer learning, and guided discovery allowed non-CS majors to learn much more about computer programs and tools, and grading criteria held students individually accountable within their disciplines but also emphasized group collaboration.

Index Terms – Computational thinking, Gerontechnology, Interdisciplinary, Teamwork.

INTRODUCTION

While specialized knowledge and skills are the hallmark of modern society, the size and complexity of contemporary problems often require cooperative effort to analyze and solve. Therefore, experiences with skills, methodologies, and tools for effective interdisciplinary collaboration and structured problem solving are vital for preparing students for future academic and professional success. These needs encompass both hard skills, such as project decomposition and resource management, and soft skills, such as creative thinking, group communication, and teamwork.

However, as the overwhelming majority of the current higher education curriculum is organized based on specialized programs of study, students often do not get opportunities to learn and experience collaboration with academics and professionals in other domains. Moreover, since such collaboration involves philosophies, methodologies, terminologies, knowledge, and tools from multiple domains, it is often difficult and straining for the students that do get such opportunities. To address these problems and provide both training and hands-on experience with interdisciplinary communication, at Iowa State University we designed and offered an interdisciplinary course, “ComS/Geron 415x – Gerontechnology in Smart Home Environments” (415x), for advanced undergraduate students. The course is aimed at disseminating computational thinking to a broader range of students and to improve students’ capability for interdisciplinary teamwork and project management. This novel course was jointly designed and instructed by faculty from the Computer Science Department, the Gerontology Program, and the Graphic Design Program to incorporate diverse faculty expertise and pedagogical approaches. The course was cross-listed to broaden student appeal and facilitate diverse recruitment.

Furthermore, the need for novel gerontechnological solutions is urgent. It is expected that the elderly population in the U.S. will more than double from 31 million in 1990 to more than 79 million in 2050, when this demographic sector will account for 20% of the total U.S. population [1]. Currently, the U.S. spends more than $309 billion annually caring for frail elderly, and that number will likely climb to more than $600 billion by 2050. Thus, systems that promote quality of life and lower the cost of elder care hold the key to any competent and comprehensive solution. Gerontechnology, and more specifically smart home technology, incorporates smart sensors and actuators with automated services and appliances, to assist inhabitants with their activities of daily living. It can compensate for older adults’ functional deficiencies; improve confidence, provide...
a sense of safety, and promote independence, while encouraging older adults to remain active and socially engaged. As such, gerontechnological innovation presents a more powerful and efficient means of elderly care than just increasing staff numbers. By freeing up human resources from mundane, repetitive, or trivial tasks, it also provides a level of ubiquitous, responsive care that is not attainable without technology, enabling caregivers to spend more time interacting with and caring for older adults.

Unfortunately, most of the (few) existing higher education courses on gerontechnology focus on exploring various existing gerontechnologies and analyzing their impacts on older adults’ working, social, and living arrangements. In contrast, our primary goal in developing this course is to produce a new, more effective gerontechnology by training engineers, scientists, and designers to communicate and collaborate about the issues of aging, assistive gerontechnology, and how older adult users interact with that technology.

Since a majority of gerontechnological solutions utilize some sort of computer-based component, computational thinking is an essential skill for understanding and developing this technology. However, formal training in related techniques, such as abstraction, decomposition, complexity analysis, and heuristic reasoning is primarily limited to students within computer science, mathematics, management of information systems, and engineering disciplines, with very little exposure for students in the arts and humanities. Our secondary goal is to disseminate computational thinking skills to students in design and the humanities, while reinforcing these concepts in computer science and engineering by explicitly explaining them and demonstrating their use. This was primarily achieved through a semester-long, interdisciplinary project in which student groups were formed with members from each department. Though the course was experimental, it was determined to improve students’ communication and collaboration practices across domains while working towards a common goal.

We further describe the course in the rest of the paper as follows: a succinct summary of related education efforts in interdisciplinary courses, smart home technology, and gerontechnology is presented in section 2; that is followed by a detailed description of the design of the course in section 3; the effectiveness of the course design is presented in section 4; and that is followed by discussion of the lessons learned and conclusion of the paper.

RELATED WORK

There are currently very few courses in gerontechnology being offered. The International Society for Gerontology organizes the Master Class in Gerontechnology series [2] for PhD students. It focuses on the relatively abstract topics of interactions between technologies, users, and goals, including cohort and generation issues, technology cross-fertilization, impacts of goals on application domains, and technology acceptance models. An undergraduate degree program on Gerontology Technology and Service Management in Taiwan [3] packages relevant courses in electrical-, computer-, and mechanical engineering, and in sociology and management, along with additional core courses in gerontology, psychology, and social work. The focus of the program is to develop gerontechnologists possessing a wide variety of domain knowledge, with special focus on either engineering or management backgrounds. Our course focus is on developing students’ skills in interdisciplinary teamwork.

CptS580 Gerontechnology I/II [4] are graduate-level courses offered by Washington State University sharing many similar emphases with 415x. Since they are offered as graduate courses, they rely heavily on student presentations and discussions, while 415x is organized as a more tightly-structured undergraduate course designed using a term project as the primary vehicle to deliver course material.

J.R. Rowland [5] identified the four principles of team teaching: organization, supportive atmosphere, participation and strengths, and made recommendations based on the experience of a mathematics/engineering interdisciplinary course. The design and instruction process of 415x follows these principles in general, but the main focus is to design a brand new course with little precedent, and imbue the capabilities of interdisciplinary teamwork within much more diverse student demographics. Kim and McNair [6] reported how an interdisciplinary team and a flexible learning environment improved students’ creativity, using a “smart dorm room” project as the vehicle for student learning. Although it shares a similar learning environment setting with the project component of 415x and an equally diverse student demographic, the two courses are not directly comparable. A project is only one of the components of 415x, and its design aims to expand students’ basic knowledge in all critical aspects of gerontechnology instead of having students apply previously acquired domain knowledge in a collaborative setting.

COURSE DESIGN

I. Course Design Process

Seven faculty members from the three departments and programs started a five-phase course design process in the fall of 2009. The process consisted of: (1) brainstorming initial course objectives, (2) identifying cross-cutting themes, (3) designing course activities, (4) integrating course modules, and (5) refining course content.

During Phase I, numerous multi-lateral and bi-lateral meetings were conducted to brainstorm and establish a consensus on the general direction, objectives, and candidate topics for this new course. Several faculty members also attended The 7th World Conference of the International Society for Gerontology (ISG 2010) in Vancouver, British Columbia, and participated in “The Competencies of the Gerontechnologist” Round Table Discussion, during which the leading experts in the field shared their ideas on the specific hard and soft skills required for gerontechnologist training and certification. A tentative
II. Course Modules and Cross-Cutting Themes

Based on faculty member input and comments from participants of the Round Table at ISG 2010, we identified the following six course modules and selected the department(s) responsible for each module’s design and instruction: the aging process, assistive technology, service-oriented computing, software engineering, design guidelines for older adults, and user study design. Considerable course materials were devoted to disseminate computational thinking skills, emphasizing basic system modeling techniques and software engineering practices. Students learned to analyze problem domains, compose software systems, and use methodologies for requirements elicitation, software design, and software testing.

- **The aging process.** (Gerontology) Without adequate knowledge of optimal, typical, and pathological aging, it is impossible to design or even assess gerontechnological solutions. This module conveys to students how sensory, motor, and cognitive functions are affected as people age.

- **Assistive technology.** (Gerontology/Computer Science) Technology can be effective in addressing many problems in senior care, but it is not a silver bullet. Students need to understand the tradeoffs of mainstream and cutting-edge gerotechnologies and to learn how such technologies can be best applied to monitor, assess, prevent, intervene, compensate, rehabilitate, and enhance the functions of users who are older or with special needs, so they can design and adopt solutions that best assist older adults and their caregivers.

- **Service computing and system modeling.** (Computer Science) Not all gerontechnological solutions are computer-based, but a majority of them do utilize computer systems in some way. An introduction to computational thinking practices allows students to acquire a structured approach to analyze complex problems, explore viable solutions, and formulate strategies to tackle the intricate issues of aging.

- **Software engineering practices.** (Computer Science) Software engineering is the study of how to specify, design, implement, and test software systems. Gaining a basic understanding of these practices allows the students, as future designers, practitioners, and policy makers, to gain an understanding of the terminology and processes used by computer engineers and scientists in order to communicate with them more effectively.

- **Design guidelines for older adults.** (Design) Effective design is critical to the adoption of gerontology by the public. Technology design needs to enable older adults to use it easily by accommodating more common conditions, such as decreased vision, strength, dexterity, stability, and momentary memory lapse, as well as more severe pathological conditions. The design must also avoid carrying any stigma of frailness or incompetence and must not be associated with death or dying.

- **Assessment and evaluation methodologies.** (Computer Science/Design) Gerontechnological solutions often are very personal in nature. The effectiveness, usability, and acceptability of gerontechnological solutions can and must be rigorously assessed with real users in the targeted demographics.

The faculty members also identified three cross-cutting themes, which are integrated with every course module in
materials and learning activities. These cross-cutting themes are described below:

- **Computational thinking.** Computational thinking is the key skill in problem solving and handling complexity. By nature, it is embedded in computer science modules, but special effort is given in assistive technology and user interface design modules to expose students to concepts such as system components, composition, and decomposition.

- **Interdisciplinary teamwork.** A considerable amount of in-class and out-of-class learning activities are designed to foster interdisciplinary teamwork. Students discuss issues and work on solutions in groups in response to instructors’ questions in class, and they are required to form interdisciplinary groups and collaborate extensively to complete the term projects.

- **Universal design.** Students are constantly being asked about how aging affects older adults’ functional capabilities, and how assistive technology can compensate for any losses. They are asked to survey and critique the designs of existing products as well as ideas generated by themselves and their peers.

III. Pedagogy and In-Class Learning Activities

Just as the objectives of the course modules were designed to include critical knowledge related to gerontechnology from each academic domain, we also intentionally designed the pedagogy for this interdisciplinary course by adopting and adapting the best practices from each academic domain for the relevant modules. In many cases, specific pedagogy and learning activities were chosen to foster one or more of the cross-cutting themes.

The traditional direct instruction pedagogical approach was adopted for part of every module, but was used more extensively for modules taught by computer science and gerontology. In order to quickly build up students’ basic domain knowledge outside of their academic majors, faculty members selected the most fundamental and relevant information in their domains and created “crash-course” lectures to introduce students to those important concepts. Mandatory and optional reading materials were also assigned to supplement materials covered in lectures.

Once a basic understanding was established, different pedagogical approaches were adopted for different modules. In computer science- and gerontology-related modules, the pedagogy of guided discovery was heavily employed. Students interacted with each other to explore ideas during in-class group discussions, which instructors summarized and formulated into principles. Students were also assigned to interdisciplinary teams for term projects and worked with their project partners to apply the guidelines and techniques to their term projects.

To help non-computer-science (non-CS) students to feel more comfortable with computing systems and develop an understanding of how they are designed and implemented, the hands-on inquiry pedagogy was adopted. A hands-on workshop was offered, where students followed a step-by-step Smart Home Laboratory Programmers’ Manual, written with non-CS students in mind and containing a step-by-step programming assignment to familiarize themselves with the smart home environment and create a working toy application that illustrates service computing principles. Students had the option of requesting help from assigned mentors if they so chose.

In both the design- and gerontology-taught modules, we heavily utilized the pedagogy of inquiry. Students were asked to create brands and user interface designs for their projects, in which they explored dozens to hundreds of design concepts. Students’ candidate designs were brought to class for a critique session during which they received constructive feedback from faculty advisors and their fellow students. Students got the chance to explain their design rationale, respond to perceptions of their design elements, and gain insights on how to create effective designs. At the beginning of the semester, the entire class took a field trip to visit assistive living and retirement communities to gain first-hand observation on how gerontechnology is deployed and used in real environments. Students also had the opportunity to interact with the nurses, aides, and administrators and explore many real-world problems. A follow-up in-class discussion helped students to further digest this experience and exchange their understanding with their peers.

Social pedagogy is also at the core of our course design. With interdisciplinary teamwork being a core objective and having students and faculty members from a variety of disciplines, the setting provided a uniquely fertile ground for peer learning. In addition to in-class discussions, many in-class and out-of-class learning activities were designed to cultivate and utilize each student’s domain knowledge, as well as provide a unique opportunity for peer learning. One such activity following the social pedagogy is the in-class presentation on a topic related to their major at the beginning of the semester. However, perhaps the pinnacle activity using the social pedagogy was the term project. Students formed interdisciplinary groups and worked on a semester-long term project that accounted for half their grades. Each group consisted of at least one student each from computer science, gerontology, and graphic design. They were required to produce a working prototype of a gerontechnology system informed from interviews conducted with real older adult users to identify real problems, gather requirements, and assess candidate solutions. The final deliverables for the project include source code, documentation, design profiles, records of interaction with older adult users, and a protocol for user study. To aid timely completion, suggested weekly group progress was outlined by the faculty members and group mentors, and weekly meetings offered regular opportunities for groups to evaluate their progress. In-class presentations and wiki-based project websites provided regular practice disseminating domain expertise to interdisciplinary audiences.
Finally, students were asked to summarize other projects and provide peer reviews to other groups. At the end of the semester, they enumerated and evaluated their own and their fellow group mates’ contributions to the project.

IV. New Pedagogical Approaches in the Second Offering

In the second offering of the course in spring 2011, because of a scheduling issue, we were unable to register design students in the class. Instead, the course structure was adjusted to include an innovative approach focusing on joint lectures and joint projects. In spring 2011, students of 415x joined with students of ArtGr 672 Graphic Design and Human Interaction (hereafter referred to as 672) for their project groups. The calendars for both classes were synchronized so students were expected to work closely on a proposal presentation, multiple design concept critique sessions, and a final demo and presentation. Additionally, the faculty members identified ten joint lectures throughout the semester, covering all the critical aspects of 415x in abbreviated crash course fashion, to keep students from both classes in sync, while ensuring 672 students get the chance to learn the critical concepts and cross-cutting themes. Both classes also joined in the field trip to a retirement community to interact with real users and caregivers.

The design of this collaboration is modeled after technically-oriented companies hiring external design consultants. Since the designers are not core members of the team, students must learn how to best utilize their external talents, prepare better-organized documents for them, and communicate and compromise when separate entities with different perspectives must work together.

In the second offering, we arranged group presentations where 415x students pitch their proposal to design students, and 672 students bid and form groups to work on the projects that interest them. In return, the 672 students present their initial brand identity and UI design concepts back to their 415x counterparts in a critique session. Students were required to give the joint final presentation to computer science, gerontology, and design faculty at the end of the semester. They were also asked to report on what they learned on this style of collaborative experience at the end of the semester.

DATA ANALYSIS

The initial results from our first offering of 415x are very encouraging with regard to our objectives. We observed significant improvements in students’ capability for computational thinking and analytical skills across the board. We also observed a marked improvement in their self-reported capability to work in interdisciplinary teams and communicate with end-users.

I. Data Collection and Analysis Protocol

The data collection for this project is based on an IRB-approved 37-question survey. Students were asked to participate voluntarily in taking the same questionnaire both at the beginning and the end of the semester (pre- and post-test). In addition to questions that establish the students’ demographics, academic backgrounds, and career plans, the majority of the questions include self-reported competencies and attitudes on various subjects, such as “How comfortable do you feel with the concept of computational thinking?” and “I rate my current level of knowledge about assistive technology as …” on a 4-point Likert range.

Data collection was administered by a separate data collection and analysis team in the absence of instructors. The participating students gave their consent and acknowledged understanding that their answers would have no impact on their grades. Participant responses were anonymized from instructors, while allowing the data team to pair the pre- and post-test data for each participant. For data analysis, SPSS v18.0 was used to conduct appropriate statistical analysis including t-tests, Spearman’s rank-order correlation, factors analysis, and cluster analysis.

II. Participating Students

In the first offering of 415x, in fall 2010, a total of 10 students registered and 1 audited. There were 6 female and 5 male students; among them 6 are Caucasian, 3 Asian, 1 Hispanic, and 1 African American. Although the effectiveness of 415x on disseminating computational thinking to underrepresented student groups can only be established over time, the 54% female and 45% non-Caucasian demographic in this initial offering shows promise. Out of the 11 students, we were able to collect 11 pre-test and 8 post-test copies of a questionnaire, but could pair only 7 of them with both pre- and post-test data. Out of these 7 student participants, 2 majored in business, 2 in human sciences, 2 in liberal arts and sciences, and 1 in computer science.

III. Findings of Interest

- The course has produced significant improvements in students’ self-reported competency in computational thinking and computer technology, as shown in the responses to the following questions on a 4-point Likert range: comfort level with computational thinking (gain of +0.8571, p<0.017), ability to apply computational thinking to analyze problems (+0.7143, p<0.008), and ability to systematically analyze and solve problems (+0.5714, p<0.030).

  A finding of great interest is that, although there are significant improvements on all questions about computational thinking and technology, the self-reported “competency to engage in computational thinking” actually dropped (-0.5714, p<0.103). This could be attributed to the fact that non-CS students did not originally have a clear understanding of what computational thinking is, and, after gaining more understanding, realized there is much more to learn.

- The course has produced significant improvements in students’ self-reported capabilities for interdisciplinary teamwork. In response to questions about
“communicating with technology domain experts” (+1.0000, \(p=0.004\)), “communicating with non-technical personnel” (+0.5714, \(p=0.030\)), and “communicating with end-users” (+0.5714, \(p=0.030\)), the effort in training students to be better prepared to contribute to interdisciplinary teamwork has seen tangible results.

As further proof of the students’ capabilities for participating in interdisciplinary teamwork, all three project groups successfully completed a working prototype addressing issues identified by real users, and produced coherent documentation, both weekly and at the end of semester, detailing their design, implementation, and user study process.

- Since the course is designed for undergraduates in computer science, but eligible for graduate non-CS credits, there was a mix of undergraduate and graduate students in 415x. Students who intended to acquire a Bachelor’s as their highest degree showed the most significant positive improvements in their understanding of several technical categories; in comparison, those intending to go on to acquire higher degrees (Master’s and PhD) show lower and mixed results.

- The collected data showed no statistically significant differences in responses from students with different majors, minors, classes (freshman/sophomore, junior/senior, and graduate students), ethnicities, or nationalities. This can be interpreted as positive feedback indicating that faculty members had successfully integrated the materials and pedagogies to accommodate students from diverse academic backgrounds, and predicted and eliminated potential disparities to allow an equal chance of growth for different groups of students.

Originally there were also concerns whether non-CS students would be able to perform well in CS modules, considering the need for a considerable amount of required background knowledge. However, analysis of the grade distributions confirms that non-CS students’ performance in CS-related modules were comparable to the CS students’ performance.

- One particular main objective that has not shown significant improvement is students’ gerontology-related knowledge. Students reported no difference in their comfort level with the concept of gerontology, and no improved understanding of the needs of the aging population. There were only minor improvements in students’ knowledge about aging adults (+0.2857, \(p=0.522\)) and knowledge about disabilities (+0.1429, \(p=0.689\)), and there was a slightly reduced interest in helping people (-0.1429, \(p=0.356\)). Our current hypothesis is that the gerontology modules were concentrated near the beginning of the semester, followed by the heavy doses of ComSci/Design lectures and learning activities, and therefore students may not have retained the knowledge about gerontology as well as we hoped.

Interdisciplinary teamwork and computational thinking are critical skills for successful professionals of the 21st century, but the current curriculum design often does not provide undergraduate students enough opportunities and training to develop those skills. Faculty members from three colleges at Iowa State University teamed up to design an interdisciplinary course in gerontechnology to hone these skills while covering the fundamental knowledge in each academic domain. With the aid of multiple pedagogy best practices, students created innovative and practical working prototypical solutions. The analysis of data from the first offering of the course shows a significantly improved self-assessment of skills and comfort levels in interdisciplinary teamwork and computational thinking and also a higher proportion of underrepresented students than is common for computer science courses.

We plan to conduct focus groups to collect in-depth, qualitative feedback on the design and impact of the course. One will be for students having taken this course in the last two semesters, and the other will be for participating faculty members, TAs, and mentors participating in the design and instruction of the course. We have also collected and will analyze pre-test and post-test data for the current offering of the course. A preliminary discussion on how to extend this course design strategy to other domains (e.g., identifying viable business plans with faculty in business schools, or identifying public policy issues with faculty in human sciences) is currently under consideration.

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CONCLUSION AND FUTURE WORK