SmartCampus-Studio: Fostering Creativity and Design Thinking with Ubiquitous Social Computing Technologies

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ABSTRACT
With globalization and outsourcing, maintaining competitive advantage often requires design innovation that takes into account local user-needs and social practices. Of particular currency to technology students, is gaining an understanding of how to engage in innovative ubiquitous computing application design. In the real world, such applications are typically designed by small teams of creative individuals in a highly iterative fashion. Unfortunately, relevant design skills are difficult to teach through traditional lecture-classroom or project-based independent study approaches which do not provide adequate feedback of iterative designs from peers, the user community and experts, or a suitable collaborative design workspace. To address this pedagogical challenge we are exploring how computing sciences design studios supported by ubiquitous social computing cyberinfrastructure that enables in- and out-of-studio learning and interaction, could be used to create the next generation of technology innovators.

Author Keywords
Studio Teaching, Ubiquitous Computing, Large Public Displays

INTRODUCTION
Innovative educational settings and multi-disciplinary collaborative approaches are needed for ubiquitous social computing (USC) education. One possible approach is to emphasize interdisciplinary design thinking and hands-on learning through a distributed studio-based educational model. Design thinking using studio-based models of education has been proved over many years to foster creativity and innovation in the field of Architecture [25]. While a few researchers in computer science (CS) have already experimented with this model [9], [12], the potential of interdisciplinary work and informal interactions enabled through USC applications in fostering creativity among undergraduate students in the computing disciplines (CS, IT, IS, HCI and CE) remains under-investigated.

This paper proposes a new type of interconnected, interdisciplinary and collaborative design studio that will foster creative problem seeking and problem solving. In these studios, students from multiple colleges and departments, such as computer science, information systems, architecture, engineering, and management, will form interdisciplinary teams and use collaborative cyber-infrastructure to explore and address key socio-technical challenges in USC. Creativity will be stimulated through semester-long design projects and real-world problem solving in an interactive environment where students can freely exchange ideas. Studio design review and user community feedback will be enabled through the use of publicly situated large-interactive touch screens and location-aware cell phones.

BACKGROUND: INFORMATION SYSTEMS DESIGN AND STUDIO CULTURE
In recent years there has been a growing recognition that the design of information systems and technology may benefit from lessons learned and approaches in Architecture and Industrial design [9]. Problems in IT are sometimes described as wicked [22] where no clear relationship between problem and solution exists. Walls et al. (1992) describe information system design theory as a composite of three elements: a set of user requirements, specific and clear system features, and a set of accepted principles to guide software development [27]. In today's highly dynamic and emergent processes user requirements may become more flexible and complex; the type of users of a system may not be accurately predicted; or there may not be a clear relationship between a problem and a solution. Markus et al. (2002) argue that new design approaches are needed in these highly dynamic contexts [18]. Traditionally, design specialists look at the degree of "structure" of a process [15] to be performed and at the user characteristics, and then build systems to support both. However, researchers complain that increasing structure is sometimes neither possible nor desirable because it introduces rigid responses to situations where flexibility and creativity are needed [21]. Boland and Tenkasi (1995) talk about the need of supporting recursive and participatory processes and human sense-making with evolutionary approaches that can creatively address unstructured and complex problems [3]. We argue that we can foster appreciation for ambiguity, creativity and novel design solutions by leveraging other disciplines and cross-fertilizing diverse, yet related, design fields. The cross-fertilization may help understanding software design with unpredictable user types and within new interaction contexts. Applying the Architecture design approach embedded in studio learning to computer science may offer

an environment to expand the structured boundaries of traditional information systems design.

In schools of architecture the design studio serves as a semester-long home for the student [8]. Design studios are where architecture students interact one-on-one with faculty to solve design problems. Studios are the central means by which architecture students learn to apply concepts learned elsewhere in the program to a single project. Design studios provide the means for highly directed, interactive instruction and the opportunity for students to integrate demonstrate and apply the cumulative concepts and issues they study throughout their learning tenure. In a studio, the student is assigned to an individual workspace with a desk, some storage space, and a network and power receptacle for use with a personal computer. Depending on the requirements of the studio instructor and the nature of the assigned project, the student can work alone or collaborate with other students. Ideally, the design studio is a highly interactive, integrative, and iterative experience. Studios usually meet for long hours (typically 4 hours) 3 times a week. During these design studio sessions, the instructor roams the studio and conducts desk critiques during which he/she works with the student on the problem at hand and discusses ways of moving forward. On some days, the studio may conduct group meetings to discuss their progress or to present a tutorial or lecture.

Typically, the studio proceeds through phases such as: 1) preliminary research, 2) conceptual design, 3) Schematic design, 4) design development, and 5) Presentation. The students usually present their work in a design review at the end of each phase. These milestones serve as an indicator of the overall progress of the studio and points out areas of weakness that may need to be addressed. Preliminary research is a phase that allows the students to familiarize themselves with the problem. This phase also includes a precedent study in which students research similar solutions to the problem at hand. These precedents are critically examined for their suitability and success as a response to the design goals they were meant to address. The conceptual design phase is meant to formulate the conceptual framework of the problem and to pose new questions and new problems. One of the hallmarks of design is that it is rarely a simple answer to a problem. Instead, it is usually a re-definition of the problem and an elegant response to a wide array of problems and desires. Schematic design attempts to solve the design problem at a schematic (i.e. not detailed) level. It presents enough information without committing many resources. Based on the feedback students receive at the end of this phase, they may continue fine-tuning their solution and then they embark on the task of developing their design. Once that phase is concluded, the students are usually given time to collect all their studies and compose a coherent design presentation. The studio concludes at the end of the semester with a formal design review that includes invited experts and guests. Work in a design studio is not as simple as described here. The design process is iterative with many dead-ends that are abandoned. It is not unusual for a student to abandon their design concept mid-way and start over. It is also not uncommon that students are asked to abandon their work for a few days to work on a more focused problem (traditionally called a *charette*). A charette allows the students to exercise rapid decision making and problem solving skills given limited resources and time.

INTEGRATING ARCHITECTURE AND COMPUTING SCIENCES STUDIOS

Some research points to studio-based educational settings as possible catalysts for fostering creativity and complex problem-solving [1], [2]. However, given the dearth of evidence and its mostly anecdotal nature, a more systematic approach and additional exploratory experiments are needed to verify the effects of various collaboration technologies, physical settings, educational settings, and social interactions on creativity and design innovation. Our approach of integrating architecture and computer science design studios with communication and collaboration technologies that support physical (co-located), educational, and social interactions is a first systematic attempt to understand how the interplay among these factors may support more creative software development experiences and outcomes.

The cyber-infrastructure for these studios will adapt and expand our SmartCampus location-aware mobile community test-bed. The students will use these devices to design, implement, and evaluate social computing applications that facilitate interactions between colleagues, friends, and even the entire campus community. A key characteristic of these studios is the use of large-screen context-aware interactive plasma displays installed in the interconnected studios and across the campus to continuously exchange information between students enrolled in the studios and the rest of the university community (Fig. 1). For instance, interested community members can leave comments or questions on the interactive displays, thus actively participating in the applications' design. In this way, rapid prototyping and early feedback will help students to refine their design and come up with novel solutions to non-envisioned problems. Because of collaborations with architecture students and others, we expect that by the end of the semester, students enrolled in these studios will design and implement novel digital/physical systems and applications that take into consideration broader issues such as the relationship of technology to physical context, ergonomics, and human behavior.

We briefly present the components of the interaction models in the next paragraphs and then discuss settings and preliminary outcomes.

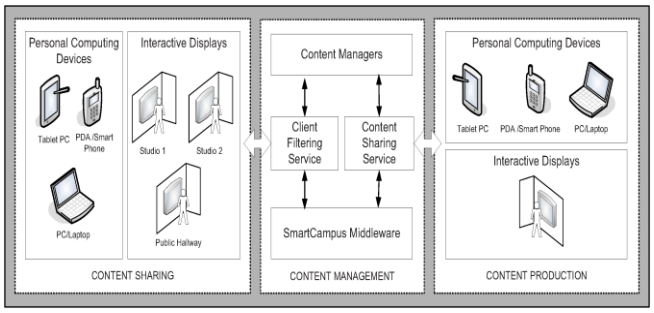

Figure 1. Interactive Poster Information Exchange in our USC

Collaboration Technologies

SmartCampus is a USC test-bed created by a diverse team of faculty from the departments of Architecture, Computer Science, Electrical and Computer Engineering, Information Systems and Management at NJIT. It serves as a dispersed laboratory for the study of USC applications, in particular systems that link People-to-People-to-Places (P3-Systems) for 1) community building; 2) co-ordination of mobile teams; 3) privacy of personal location data; and 4) security. P3-Systems are of particular relevance to face-to-face educational settings because they can transform traditional educational environments by dissolving boundaries between digital, physical and social spaces and can help motivate both online and face-to-face community participation.

We propose to use SmartCampus-based technologies to connect and blend digital, social, and physical spaces into a common inter-disciplinary educational space. By adding connecting large interactive displays to the SmartCampus test-bed will give students serendipitous community interactions in an educational setting that will allow them to explore and receive training in USC. Large-screen systems can also be used to increase informal interactions, through any of five basic interaction approaches, as: (1) Community Notice boards; (2) Media-Spaces; (3) Community Awareness Systems, (4) Walk Up and Use Personal Interactive Public Interactive Surfaces, and (5) Proactive Displays. To integrate the interactive public displays in the SmartCampus system architecture, we are transforming the current Plasma Poster client-server architecture [5] into a service oriented architecture similar to the one used by SmartCampus. The new architecture for content sharing is broadly presented in Fig. 1. The posting infrastructure will be abstracted into a content sharing service. This service will receive requests from a multitude of client applications that need to publish cyber-infrastructure educational information on the public displays. For instance, an instructor may use her/his PC to post an interesting article, and subsequently, a student can read this article and post a question using his/her SmartPhone. Furthermore, new content can be generated by users interacting with the display. To simplify the content management, users are asked to annotate the content with meta-data. Where possible meta-data will be automatically extracted and leveraged for content organization, indexing and filtering. The meta-data is used by the content filtering service that decides in real time what type of information to display on each individual plasma display.

Physical Settings

We intuitively understand that the physical setting and ergonomic conditions surrounding deployed technologies influence their effectiveness. In educational settings, researchers have reported that the physical setting had a direct impact on students' satisfaction and productivity [4], [20]. With the help of architects, researchers at Monash University have specifically re-designed an old classroom to provide a 'precinct' of inter-related design areas including: i) a design studio, ii) an Internet café, a meeting room, and an area for technical support. Their research results, while preliminary, tends to indicate that the physical setting of a studio resulted in greater satisfaction among their students [17]. In the workplace, more emphasis is being placed on innovative design of physical space as a vehicle for excellence. For example, based on a four year research project conducted at the MIT School of Architecture and Planning, the Space Planning and Organization Research Group (SPORG) have discovered the significance of an effectively designed workplace on business operations and employee productivity [11].

With respect to our proposal regarding the deployment of interactive displays to seek greater feedback and interaction among students, the design literature provides several guidelines for their effective placement [13], [19], [5]. Locating these displays will be essential to the success of the implementation of the overall vision. Some of the above issues are not well-covered in the literature and will have to be addressed through exploratory action-research for an effective implementation of our educational USC. One of the main reasons we are proposing an interdisciplinary approach that includes architectural students is to bring forth issues of context and ergonomics and include them in USC design problems introduced in studio. Student teams will initially carry out these experimental and temporary installations in the context of design classes that explore blended spaces and teach about USCs, and in the process learn about design with a concern for physical space and activity analysis.

Educational Settings

The research literature indicates that an emphasis on design thinking and a studio model may be effective in fostering creativity [26]. Unfortunately, this research area is under-investigated and the evidence remains largely anecdotal. Researchers from the University of Queensland, Australia conclude that their implementation of a studio-based educational model: "is still in its infancy. Studio teaching is very different to any form of teaching which the School has attempted in the past, and we are still learning about the most appropriate methods for carrying it out." [10]. In the field of Architecture, design culture is mature yet surprisingly under-investigated. As Donald Schön has noted, design should be treated "not primarily as a form of

'problem solving', 'information processing', or 'search', but as a kind of making" [24]. Few researchers in the discipline of design have outlined general methodologies and strategies characteristic of creative design-based thinking. For example, Nigel Cross argues that in fact creativity is not achieved through a blind creative leap, but rather by 'bridging' partial models of the problem and the solution constructed side-by-side [7].

Our proposed design of Architecture and CS studios closely interacting 'side-by-side' either using face to face meetings or coordinating progress through virtual and interconnected displays intends to generate more opportunities for the achievement of creative outcomes. On the computing sciences side we will use the scenario based usability engineering approach to structure the studio work [23]. This HCI approach is well suited to studio based teaching, with its phases of analysis, design, prototype and evaluation. This will be complemented by the use and teaching of various complementary techniques such as paper prototyping, storyboarding, etc.

Social Interactions

The role of casual interactions in fostering creativity is a new research area that we plan to explore. The literature on the subject is limited. In the discipline of design, casual interactions have been observed to help designers solve problems collaboratively [16], [14]. However, few researchers have experimented with the use of lightweight and informal interaction encouraged by location-aware social matching systems and interactive public displays. Researchers from MIT have used group, location and event information to bridge online and offline activities of learning groups [28]. They developed a system titled StudioBRIDGE based on Instant Messaging to help students initiate online and offline interactions by allowing them to be aware of nearby people, groups, and community events. Interestingly StudioBRIDGE was tested in MIT's Architecture Department using students working in open studio spaces. Yee and Park report that while this was only a "pilot study with a small number of users" they report that 75% of the students felt more connected to other people using the system and that 80% of the students indicated that they had, or anticipated having online conversations with someone they have frequent face-to-face conversations with.

Churchill et al (2004) report on the use of plasma posters designed to facilitate informal content sharing and provide guidelines on their design and deployment such as: i) Participatory design, ownership, ii) Low effort to use, fit with existing practice, iii) Means not ends, iv) Maintain infrequently used functionality, v) Continuity of service, vi) Simplicity of form and function, clear identity, vii) social (Inter)faces, viii) Neutral digital spaces, and ix) Synergestic (networked) displays [6].

DISCUSSION AND WORK PLAN

We are currently conducting our first pilot of interconnected architecture and computing sciences (CS, HCI, IS and IT) studios to explore the pedagogical approach, integration and understand preliminary outcomes. Students are researching the use of large interactive displays and associated social networking software. They are analyzing the best locations for the placement of these displays and then use them in the course of their design work. Given that the pilots are underway, only preliminary and anecdotal results are available. We have been successful in linking studios that are (a) *interdisciplinary*; (b) *interconnected* through a variety of communication and visualization tools; and (c) *freely interactive* by leveraging multiple means of formal and informal exchanges among the students involved. Interdisciplinarity has been achieved by conducting the studios with highly diverse student populations. Teams in the CS studio have been assigned multiple design and development projects and have completed literature reviews, design reviews and project mock ups by eliciting feedback form the students in the architecture studio. Collaboration has been achieved primarily through face to face meetings, instant communication devices and emails as well as joint review sessions.

Starting from Fall 2007, studios will also be connected through interactive plasma displays placed in each studio, and later through the campus community through public plasma displays which will be conveniently located on campus to solicit both casual and formal interactions from passers-by (i.e. asking real-time feedback on design, usability, usefulness, etc.). While it is still premature to articulate outcomes, results from the experiences will be captured through open-ended interviews at the end of the semester and will report on the perceived learning, social and design outcomes. They will also guide the refinement of future studio along with in depth field studies.

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