Maker-Oriented Learning in Undergraduate HCI Courses

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Abstract
As the demand grows for active learning in undergraduate HCI courses, instructors must adapt their curriculum to provide applicable hands-on learning experiences for their students. This adaptation uses a maker-oriented learning approach that embodies elements of the maker movement that can enrich an overall pedagogical approach to teaching HCI, as well as concrete activities that provide unique learning opportunities for students. In this course, we present this maker-oriented learning approach in two sessions. The first session consists of an introduction to the maker-oriented pedagogy and guiding principles for teaching HCI topics, as well as a design activity for transforming traditional classroom spaces into ad hoc design studios. The second session focuses on applications and activities to introduce students to hands-on design experiences that utilize maker-oriented technologies to develop interfaces.

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Introduction
The purpose of this course is to introduce instructors teaching undergraduate HCI courses to a maker-oriented learning approach that engages students in a studio-based learning environment. Maker-oriented learning is an effort to implement motivations, technologies, and methods from the maker movement, into computer science classrooms with the intention of increasing interdisciplinary and collaborate learning. It looks to directly address the growing demand for STEM education in undergraduate programs by reinforcing abstract concepts through practical, hands-on activities. These physical prototyping exercises have the potential

	Class Size	Times Taught
Human-Computer Interaction	~55	2
Mobile and Ubiquitous Computing	~65	2
Intro to Prototyping	~22	3
Prototyping Interactive Systems*	24	1

Table 1: Courses taught using a maker-oriented approach. During these courses, the methodologies and activities presented here were developed and refined. *All courses were undergraduate courses with the exception of Prototyping Interactive Systems.

to promote transfer of HCI topics, and help students learn to work across multiple disciplines.

We have observed a surge in educational efforts to embrace the maker movement that has been growing in the United States over the last decade. This movement is easily identified by its community that creates physical artifacts that often times embrace technology and crafting. In many instances is has become synonymous with "do-it-yourself" (DIY) communities. There exists a wide body of research that has studied such communities with resect to robotics, textiles, computational kits, and K-12 computer science courses [1-4]. Our approach furthers this work by implementing these ideas in undergraduate courses, such as human-computer interaction and mobile and ubiquitous computing. We seek to help instructors promote a deeper understanding of HCI topics by taking advantage of the discovery learning inherent to the maker movement. This approach encourages project-based learning to help constrain and scaffold student learning [5]. Furthermore, it borrows heavily from studio-based learning environments where instructors and students constantly facilitate a creative process, including the use of tools and materials during the prototyping process and a critique process to reflect and iterate upon work.

The methods and activities discussed during this course have been developed over the past two years through a number of HCI-related classes (Table 1). These classes have presented an opportunity to test out this approach in a variety of situations including class size, diversity of student majors, and classroom arrangements. This has allowed us to tailor this approach to make it suitable for many HCI-focused courses.

A Maker-Oriented Pedagogy in HCI

A maker-oriented learning pedagogy in HCI combines a variety of HCI-, maker movement-, and studio-based approaches to create an active learning environment. Central to this pedagogy is the idea that embodying HCI ideas in physical artifacts creates a level of engagement and visibility that is not available in a traditional curriculum.

Increasing Visibility of Student Work

The visibility of student work that is afforded through a maker-oriented HCI course manifests itself in two distinct ways. The first way is through a series of in-class prototyping exercises, discussed in more detail in the next section. These rapid prototyping exercises allow students to explore HCI topics through a fail-fast approach that produces a tangible artifact that demonstrates their understanding.

The second way to increase the visibility of student work is through student-lead critiques of out-of-class projects. Often times, semester-long projects remain relatively unseen until a final presentation at the end of the semester. By espousing a critique method common in art and design studios, students become responsible for their peers' work by offering suggestions and feedback on both positive and negative aspects of the work. These critiques are staged in the classroom with a portion of students presenting simultaneously throughout the space while remaining students act as critics and visit each presenter to offer feedback. We have developed materials to help students through this process, as many of them are unfamiliar with a formal critique process. For example, critique notecards help guide student critics in the type of feedback they should give. At the beginning of a critique student

Figure 1: Traditional kit-based arrangement of tools and materials (top) versus a workbench-based arrangement of tools and materials (bottom). Traditional kits can be assembled and disseminated to student groups, whereas workbench arrangements require students to come and select what they want to use. Each can be suitable depending on the activity and are easy for instructors to prepare.

critics randomly select a few critique cards from a pile that contain prompts like "comment on a strength of the design" or "describe a weakness and suggest an improvement" or "ask a question." Student critics then use these cards at each station to ensure that student presenters are receiving feedback on their projects.

Practical Classroom Considerations

Maker-oriented activities like critiques and rapid-prototyping exercises are flexible enough to be taught in a variety of classroom spaces, thus removing the need to have a purpose-built lab. However, in our experience teaching with this approach, a number of simple considerations can be made to better facilitate learning and decrease the amount of preparation needed to support this approach.

The number of students in a class can immediately become a concern for instructors because of the daunting task of preparing materials. We have overcome this obstacle in two ways. The first is by reducing the overall number of materials required by having students work in small groups (generally groups of 2 or 3 students). When faced with a group of 60 students, this limits preparation to 20 kits of tools and materials and becomes much more manageable. The other way to reduce preparation is through using a traditional kit-based or workbench-based approach to distributing tools and materials (Figure 1) as discussed in the *Toolkit & Material Considerations* section.

The classroom arrangement itself can also simplify this approach. Easily movable tables and an abundance of power outlets allow students to quickly organize their space to better suit a variety of activities. Furthermore, brainstorming surfaces, such as dry-erase boards and large notepads help students thoughtfully communicate their designs before committing to a physical prototype.

Finally, some activities require tools that are not practical for in-classroom use because of time and size constraints. 3D printers and laser cutters are very useful for creating physical artifacts, but the time required to operate them will not generally fit in a class session. Thus, having access to on-campus prototyping facilities such as fabrication labs or makerspaces is becoming increasingly important. Fortunately, these resources are becoming widespread across campuses and students are able to access to these tools.

Prototyping Activities to Support Maker-Oriented Learning

The maker-oriented learning approach to teaching HCI courses relies heavily on practical activities for students to practice their newly acquired knowledge. These activities are carefully crafted such that they can be implemented in most classrooms, so long as a few considerations are made. We will discuss these considerations, as well as three types of rapid prototyping techniques that make such activities possible. The first type of rapid prototyping, manual prototyping, involves participants working together to create a paper lantern with a novel interface. The other prototyping techniques (automated prototyping and interactive prototyping) will be discussed.

Toolkit and Material Considerations

Preparing tools and materials for large groups of students can be troublesome, particularly when introducing new concepts and methods of fabrication. Because of this, considerations can be made in grouping tools and materials to help scaffold learning.

Figure 2. Participants in the Manual Prototyping Activity created this head-mounted paper prototype lamp that would display the wearer's emotional state by sensing changes in their brain waves.

Organization of tools and materials in traditional-style kits, for example, present a way to help productively constrain students' workflow and allows them to focus on a particular prototyping technique or problem-based HCI topic. However, we have also explored a workbench model of organizing materials that supports a project-based approach to designing interfaces.

Manual Prototyping and Interactive Lamps

The maker-oriented approach and classroom considerations can best be explored through a hands-on activity. During this activity, participants work in small groups to brainstorm and prototype an interactive lamp that shows emotion. This manual prototyping exercise uses foam core and moldable plastic that allows participants to rapidly build physical forms that embody their idea. By streamlining the prototyping process with simple materials, participants can easily explore the connections between technology, human emotion, and interfaces (Figure 2). At the conclusion of this activity, participants will regroup and critique each other's work to help iterate on the designs.

Introducing Automated Prototyping in HCI

The maker movement is most easily recognized by its embracing automated, digital fabrication tools such as 3D printers, CNC routers, and laser cutters. As these tools continue to populate labs and fabrication spaces on campuses, there is a unique opportunity to use them in conjunction with traditional HCI curriculum.

In order to facilitate the use of such tools, however, instructors and students must have an adequate understanding of basic two-dimensional and three-dimensional design. Thankfully, this process has become increasingly accessible to amateur designers through free and user-friendly software such as Inkscape, Sketchup, and 123D Design.

Teaching Interactive Prototyping

As students master physical prototyping techniques and HCI concepts, they will increasingly turn to inexpensive microcontrollers, such as Arduino, to bring their prototypes alive. This allows students to explore a broad range of topics, particularly physical interfaces, and lets them leverage existing programming skills with their emerging physical prototyping abilities. By scaffolding student experiences with toolkits (such as the Sparkfun Inventors Kit) and sufficiently challenging activities, many students are able to quickly fabricate interactive devices that are able to demonstrate a well-formed understanding of HCI.

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