

Capstone Design Experiences

Born from ABET requirements for open-ended group projects to “cap” traditional computer engineering curricula, capstone design courses have spread across computer science and computer engineering curricula and offer many distinct advantages to both students and faculty.

For students, the main goals are to connect and synthesize the many topics covered in more traditional courses through an experience that comes close to what students will face in employment and/or graduate school, namely, working on a team (often inter-disciplinary) to develop a project concept, determine a plan of attack to deal with unknowns and possible contingencies, work with “customers” to refine requirements, and implement a working prototype that can be used to evaluate the idea. Students can also use these capstone experiences to “specialize” their degree. For faculty and their departments, capstone design courses provide a way to drive pedagogical innovation and modern topics into the curriculum and to integrate teaching and research activities more closely.

The University of Washington’s Department of Computer Science & Engineering has a particularly rich set of capstone design courses, which has been steadily expanded over the years to expose students to the ever-widening variety of careers offered by the field as well to demonstrate the societal relevance of technology. Current examples include:

University of Washington Capstone Design Courses

Hardware design and embedded systems	The original computer engineering capstone design course, this offering focuses on the development of novel mobile and personal sensing devices applied to health care, environmental sensing, and, more generally, in ubiquitous computing scenarios.
Video games	This course began as a collaboration with Microsoft in 1999. It exposes students to modern game engines and libraries to create novel multi-player distributed video games.
Digital animation	This highly successful interdisciplinary course sequence began as a collaboration with Pixar in 1996. CSE, Music, and Art students work in teams to create innovative short animated films.
Computational biology	Students develop new algorithms for comparing gene sequences to extract information such as common genetic markers and likely evolutionary developments.
Accessibility	Focusing on the needs of our physically-impaired population, this course has developed many new devices to help deaf and blind users navigate and communicate in a complex world.
Urban simulation	Builds visualization and simulation tools for urban development with particular attention to transportation congestion.
Information and communication technology for developing regions	Develops novel devices and applications that are appropriate for developing world contexts in application areas as varied as health care, environmental monitoring, micro-finance, and transportation.
Advanced Internet systems	Exposes students to the technologies used to build today’s web applications ranging from search to e-commerce.

Scalable systems: design, implementation, and use of large-scale clusters	This course began as a collaboration with Google in 2006. A recent project helped a student become a key member of the small team that developed the Google Maps bicycle route mapping feature.
Other current UW CSE capstone design course offerings include ...	Robotics, operating systems, distributed computing, tablet computing.

Students take one or more of these capstone design courses, in the junior or senior year. For students, the benefits include **synthesis**, **realism**, and **deep specialization**. For the program as a whole, the benefits include:

- **Experimentation** for later inserting technology elements into traditional courses. For example, the sensing devices prototyped in the embedded systems capstone led to a new embedded systems course based on wireless sensor nodes.
- Multi-quarter multi-disciplinary **design experiences** that give students more time to explore a design space. The capstone format allows for this much more easily than the traditional curriculum.
- Easier **connections between faculty members' research and their teaching**. The more substantial nature of capstone projects has led to many publications in workshop and conference venues and allows undergraduates to team up with graduate students on projects that feed into a research program.
- Technology collaborations leading to **stronger ties with industry**. The scalable systems capstone led, in part, to the establishment of the Google/IBM Academic Data Center and the NSF CluE (Cluster Exploratory) programs. Embedded systems capstones helped make UW an attractive location for one of Intel's university research laboratories.
- End-of-course **videos capturing what students actually are able to accomplish** as a result of the program. These videos have been used at graduation ceremonies to inform parents, at recruiting events to inform prospective students about the many directions their careers can follow, and at CSE-community conferences publicize our curricular innovations.
- Expanded **media coverage** for CSE activities by making them more accessible to a wider audience through much more user-oriented and substantial projects with interesting human-interest stories focused on students. This exposure helps immensely with recruiting and with the image of the field.

Common Themes and Methods

The common themes and methods that emerge in these courses are:

- **Integrate** - a team design experience makes concrete the foundational concepts introduced in related courses.
- Build on **student-accumulated knowledge and experience** to permit greater choice in the formulation of individual projects, even if they remain constrained in theme (e.g., a game, a race car, a networked appliance) or choice of implementation approach (software-only, embedded system, etc.).
- Introduce **human-centric design experiences** through projects that involve human-directed inputs based on system communicated outputs. Encourage the development of communication skills through frequent design presentations, project write-ups, and engagement within the project team and with external "customers."

- Introduce **constrained design** by imposing user requirements and limitations to the implementation approach on the projects. Evaluate projects not simply on functionality (e.g., meeting functional requirements), but also on performance, cost/performance, and elegance (e.g., fewest components, lines of code, etc.).
- Use **cooperation** (e.g., sharing tools and libraries) and competition (e.g., bragging rights) where appropriate to undertake larger design or to motivate students.
- Re-conceptualize curriculum around the **project focus** to introduce materials “just in time” to be useful in project design and implementation.

Artifacts

Pointers to sample videos, press coverage, and papers that have resulted from our capstone courses are provided below:

- Videos of all of many of our capstone courses: <http://www.cse.washington.edu/info/videos/>
- Local TV coverage of the recent Accessibility capstone: <http://www.komonews.com/news/local/87737592.html?tab=video>
- Scalable Systems course chronicled in *Business Week*: http://www.businessweek.com/magazine/content/07_52/b4064048925836.htm
- Animation capstone films have been shown at international, national, and local film festivals including two accepted to the upcoming Seattle International Film Festival in May 2010 and another being presented the Smithsonian’s National Museum of American Art.
- Computational Biology projects presented as papers and software:
 - J. Hughes, J. Maurer, T. Roseman, A. Prakash, and M. Tompa, "Discovery of Yeast Regulatory Elements Phylogenetic Footprinting" (extended abstract). *Systems Biology: Genomic Approaches to Transcriptional Regulation*, Cold Spring Harbor Laboratory, NY, March 2006.
 - Shane Neph and Martin Tompa, MicroFootPrinter: a Tool for Phylogenetic Footprinting in Prokaryotic Genomes. *Nucleic Acids Research*, vol. 34, July 2006, W366-W368. Web interface for MicroFootPrinter available at <http://bio.cs.washington.edu/MicroFootPrinter.html>
- Development of a new mobile data collection tool, Open Data Kit (<http://www.opendatakit.org>) for smart phones began in our ICTD capstone course.
- Personal health tools and ubiquitous computing have been a common theme in our embedded systems capstones including the following papers:
 - G. Borriello, A. Liu, T. Offer, C. Palistrant, R. Sharp. WALRUS: Wireless Acoustic Location with Room-Level Resolution using Ultrasound. 3rd International Conference on Mobile Systems, Applications, and Services (Mobisys05), Seattle, WA, pp. 191-203, June 2005.
 - D. Noose, J. Miyazaki, C. Hartung, G. Borriello. Insulin ActiveCalc: Utilizing Activity Measurement to Improve Blood Glucose Control. Workshop on Interaction with Ubiquitous Wellness and Healthcare Applications (UbiWell) (at Ubicomp07), Innsbruck, Austria, September 2007.

Links to UW CSE capstone courses can be found at: <http://www.cse.washington.edu>.