Managing Real-World Projects in Capstone Computing Courses

Team Assignment

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Abstract

Capstone course projects based on real-world needs can be considered as the basis for an engaging and memorable educational experience. Interacting with real customers can provide much needed opportunities for students to practice communication and other soft skills while connecting students with the customers’ community. In addition, projects that have the potential to make a positive impact on the world have been shown to be particularly motivating to students and can serve to attract and retain students in the field of computing. In other words, the capstone course is designed to integrate and apply concepts and skills learned throughout the curriculum to a practical real-world project.

This paper is the result of study of several universities to discover how they manage real-world projects in each of their respective capstone computing courses and to survey different aspects, effects and benefits of it for the faculty, student, University departments and the firms as sponsors and customers.

Introduction to the Capstone Project

Over the last two decades, capstone courses have seen improvement. Faculty have developed new approaches to capstones and have discovered some benefits beyond their expectations. Capstone courses help students to integrate the subfields, skills, and perspectives of their major.

Capstone design courses are the best opportunity in the curriculum to address these mentioned outcomes. Even in that context, it can be challenging for students to experience diversity while also involving them in projects that have the potential to impact the world.

Exposing computing students first-hand to different cultures and a global perspective is especially difficult in technology related programs where course requirements can make pursuing dual majors or studying abroad particularly challenging.

Universities offer capstone course projects in single and double semesters, often with the latter reserved for bachelor programs. At University of Nevada Reno, Department of Computer Science and Engineering, The first course provides students with the necessary background for applying sound software engineering practices. In second course the emphasis is on team collaboration with the primary objective being the development of an original, functional, industry-strength software-intensive product. [2]

Some universities suggest capstones be taken as the last course whereas others offer it in last semester. University of Huston’s capstone project take place within the last twelve credit hours of study. According to the Computer Science department at the University of Huston(which offers Master of Science Capstone Project):“the capstone project course gives students comprehensive experience working on real-world projects as part of a team”. [3]

At Seattle University, students in the Master of Software Engineering (MSE) degree program are required to participate in a capstone project sequence involving a significant software project. These courses are normally among the last courses to be taken in the MSE program, after completion of the core courses. [6]

Course Structure, Project Size and Environment

There are several ways to structure courses when designing capstone projects. The following are result of our research:
At the University of Nevada, several lectures are dedicated to the human-computer interaction aspects of the projects developed, as the instructors firmly believe in user-centric approaches for creating software-intensive products. For this purpose, short video clips of projects developed in well-known human-computer interaction laboratories such as those at IBM, HP, Stanford University, MIT, and the University of Maryland are also presented.

The teams of students have one academic semester (about 15 weeks) to develop their projects. Typically, the projects have a predominant software component. However, some hardware development has also been included lately and is encouraged (to encompass the challenging category of embedded systems). Throughout the semester the teams report on their work through documents (deliverables) submitted to the instructors and through project presentations delivered during regular classes. A project website is set up at the beginning of the work and updated regularly during the semester. An internal project demo (“dry run”) is presented to the instructors during the last week of the semester. Few days later, at the public CS Senior Projects Workshop a final presentation is delivered, accompanied by a poster and, on request, by a public demo.”...”Project concept topics can be proposed by the students, by the instructors, and by the external advisors. The concepts are validated and the projects receive the “green light” only after brainstorming and analysis meetings of the teams with the instructors are held.” [2]

At Seattle University, the primary purpose of the MSE Project is to provide a practical learning experience and a culmination of their course work for MSE students. Throughout the project activities, the students must clearly demonstrate their mastery of the collective material studied in the MSE program, and directly apply their learning. Early in the calendar year, the CSSE Department solicits proposals for software projects from potential industry/business sponsors. The, College Project Director invites proposals for projects and asks that sponsors provide material support for those projects. This support will be in the form of restricted donations to the Seattle University, as well as various hardware and software resources that may be required for specific projects. The support received by the CSSE Department is pooled to cover direct costs of projects, and to cover the costs of continuing support and upgrade of computer lab equipment. [6]

At Carnegie Mellon University (CMU), there is a Human-Computer Interaction Institute (HCII) which is an interdisciplinary community comprised of students and faculty and is decided to research and education in topics related to technology that supports human activity and society. The first few months of the project consists of user research and brainstorming, while the user research phase begins via students consulting with their customer/client and researching their background. The next few months comprise of a selection phase, and after receiving customer input, ideas are narrowed and a selection as to which one or few to pursue via prototyping and user-testing. Weekly iteration cycles are implemented, and prototypes and designs are refined and adapted into a final proof of concept. [1]

In the iSchool’s program, at the University of Maryland, the team experience is coupled with a capstone project, both of which together comprise of six credit hours within the total required 36 credit hours for the Masters in Information Management program. From the diverse settings at all levels, such as corporations, small businesses, academic institutions and non-profits, the school solicits complex and dynamic problems for the students to tackle. These problems are real-world problems that demand a variety of expertise and soft skills. Students take these two courses at the end of their program so that they can hone the skills learned from all of the previously taken courses. The capstone is undertaken in the last semester of the program as a “proof of competency.” The project emulates a consulting relationship, where there is “accountability for decision-making and deliverables are clearly delineated.” [9]

The goal of the University of Minnesota’s capstone project is to demonstrate fluency with the tools of scholarship and professional practice in the field, an ability to independently plan and carry out a non-trivial piece of work, and an ability to present work in written and oral formats. The capstone project can count for 2-6 credits in the program, and is expected to require at least 50 hours of effort per person per credit. The policy in MSSE is that if a student selects a topic that requires a substantial technology-related learning curve, then that portion of the effort is over and above the effort expected for the Capstone project itself. The Capstone project can take many forms, depending on student’s interests. It must be educational, have a research component, and relate to the Software Engineering program. [10]

At La Salle University, their program focuses on practical application of the strong conceptual knowledge that students gain throughout their degree program. [5]

Harvard University offers a Master of Liberal Arts in Information Technology from its Extension School with capstone courses in both software engineering and in information management systems. The courses are a collaborative effort among a small group of students where they can showcase their
technical knowledge, work within constrains, and apply lessons learned throughout the course to build an end-to-end solution which is both comprehensive and cost effective. The course consists of lectures, case studies and a team project which are a blend of topics the students have learned throughout their degree program. [4]

Some universities simulating real-world situations need to provide a development-enhancing environment, which can be costly and complex. According to the article ‘Designing a Capstone Course to Simulate the Industrial Environment’ by Greg Speegle from the Department of Computer Science at Baylor University: “A primary concern for an academic institution is the cost of the computing environment needed to simulate the workplace. Although the computing resources varied between the developer, tester and PM/S teams, none of the environments had excessive capabilities”...“Virtualization is common, and should be encouraged. Another challenge within the environment is the diversity of software required, particularly in legacy systems.” [7]

Nature of Projects

As the nature of most capstone projects tend to lean towards creating a real-world situation and/or assisting a company with a real problem they are experiencing, projects run the gamut, ranging from general applications to special industrial application software. Other projects are based on academic needs from the same or different departments. In both cases the nature of projects usually is based on customer needs.

At university of Huston, the nature of the teamwork varies from project to project. Popular areas include Web development, application development, database-driven application, network programming, scheduling, workflow, and graphics. [3]

At the University of Minnesota, projects are a technology analysis: Analyze and compare competing approaches or products relative to some application or class of problems; Software design and implementation: Analyze a problem, research known solutions and products that address the problem, develop a design and a plan, and choose some of interest or are challenging. [10]

LaSalle University gives students great breadth of scope in selecting the nature of their project. Pending faculty approval, projects can focus on advanced data structures, GUI application design, database application design, web application design, graphic design, Operating system detailed examination, social and ethical issues, GUI programming design, networking intranet/internet design, groupware design, expert system design or computer based training design[5].

At Harvard University, topics for the study can include: enterprise applications, business-to-business (B2B) portals, enterprise data management, building IT business cases, IT architecture and integration, and ITIL (Information Technology Infrastructure Library). [4]

Faculty, Students, Sponsors and Customers

Carnegie Mellon HCCII faculty members mentor and advise the student projects each year. The collaboration between students and faculty members of all disciplines is of utmost importance to the nature of the capstone. They assist in setting up scope, time management and communication efforts across the team, also facilitating communication between the student group and their corresponding customer/client. Major corporate sponsors and Fortune 500 companies work with the groups of students on real-world issues the sponsors may be facing at the time of the project. The sponsor is required to meet with their group in person three times during the project in Pittsburgh, and be available for weekly ‘meetings’ as a manager would do in a real-world situation team scenario in the industry. Two to three Carnegie HCII faculty members mentor/advise the student projects each year. They meet with each team on a weekly basis, and provide ongoing lectures throughout the semesters. They are there to help set scope, manage time, and ease communication across the team and between the educational sponsor and the student team. [1]

The University of Maryland’s iSchool MIM program puts the instructor(s) running the capstone in charge of forming teams. At the University of Minnesota, there are four parties who play important roles in the capstone project process:

• The student presumably wishes to complete the MSSE degree.
• The advisor supervises the student’s work.
• The MSSE program office in UMSEC keeps records, facilitates interactions with the Graduate School, and keeps a library of past successful projects to help students gain perspective on the process.
• The Director of Graduate Studies (DGS) is responsible for the academic quality and consistency of the program. [10]
At La Salle University, the project "customers" are at the discretion of students and often include local businesses, employers of the students and those companies that have submitted proposals to the university. Projects are guided by the professor of the course. [5]

At Harvard University, the project customer is a fictitious company for whom students can investigate enterprise-scale, complex software applications and issues surrounding their development and deployment in large business settings. The collaborative project effort is actively coached by the professor and teaching assistants. [4]

University of Houston states: “Our industrial partners sponsor most projects. These firms provide initial project specifications and mentoring. Partner companies include Tietronix, AtLink Communications, United Space Alliance, GHG Corporation, and MiniCheck-OCR. This partnership offers the students invaluable industrial experience, significantly helping them find jobs after graduation. Some of them were hired by the mentoring companies. “ [3]

At Seattle University, both the undergraduate and graduate student capstone project sequence involving a significant software project. These projects are sponsored by local companies and reflect the real need of these organizations. Students work in a team with guidance from a faculty advisor, and interact with the sponsoring company throughout the year to identify the project requirements, design and develop the solution, and plan for the future development and maintenance activities. The faculty advisor is expected to: meet with the students as a team early in the summer preceding the project year, make clear the purpose of the Project, provide clear and complete information as to grading policy, criteria, and process, advise as appropriate in the preparation of the Software Development Plan, meet initially with the project team. [6]

At Washburn University, students work on actual projects for real customers. The customers could be local businesses, industrial partners, and units within the University. As with the other models, students apply software engineering techniques, work in groups, write and test software, and prepare user manuals. The primary difference is that this is done for the benefit of a real customer. [8]

**Team assignment, size and method**

According to the Greg Speegle from department of Computer Science at Baylor University: “although it is agreed that students must work in teams, the size of teams for capstone projects varies across universities. For some projects, the teams are typically on the order of three to seven students. Larger projects consist of teams of 10-12 in or even one team for the entire class. From the interview process, simulating the industrial environment requires teams of about 12-15 members”...“A project team will consist of no more than fifteen students, and ideally no fewer than nine. In order to accommodate the one project – three parts construction commonly found during the interviews, the team will be divided into three groups development, testing and PM/S.” [7]

At University of Nevada “Each project team consists of either three or four students and has at least one ‘external advisor’ and/or sponsor.” [2]

At Northwest Missouri State University (NWMSU), students are broken up into interdisciplinary teams composed four or five students for electronic portfolio critiques. Team selection is mixed with students from each of the three concentrations: Computer Science Programming, New Media and Visual Imaging. Instructors form interdisciplinary teams based upon students' technical, design, communication and social abilities to ensure that the teams are well balanced. [11]

At Carnegie Mellon’s HCII, teams consist of five to six MHCI graduate students completing their final semesters. Each team is balanced with students of backgrounds ranging from design, technology and social sciences. The students choice and background weigh into the decision of matching a student with a sponsor at the beginning of the course. If a project is heavily technical, then the faculty advising the project appropriately match more technical students to the project to create a team that will be best able to complete the task optimally. [1]

The University of Maryland (UofM) has teams ranging between four and six students for each site proposal. The MIM semester instructor(s) places teams to corresponding sponsors. While all students are registered in the same program (MIM), many of their course work usually has varied quite a bit to allow for a range of experience within the collaboration. The faculty also chooses from all of the sponsor proposals which projects the students will be undertaking as well. [9]

At University of Minnesota (UM), capstone projects may be group or individual efforts. [10]

At La Salle University, The MS Computer Information Science program offers both one and two semester capstone projects. Students can undertake them alone, in group with peers for more complex projects, or partner with an external company[5].

At Harvard University, Students collaborate in small teams. [4]
Table 1: Method of student assignment

<table>
<thead>
<tr>
<th>Method</th>
<th>Nevada</th>
<th>NWMSU</th>
<th>Seattle</th>
<th>UofM</th>
<th>UM</th>
<th>La Salle</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructor-chooses students randomly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instructor-using student abilities</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Instructor-using student abilities and other student information</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Students choose team members</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>1</td>
</tr>
<tr>
<td>Hybrid approach-instructor and students together form teams</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Other methods</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Project deliverable

At Seattle University, the deliverable is a software development plan, requirements document, draft architecture, and exploratory software releases (iterative development process). A draft proposal for the research component of the project must be submitted at this time. A review board meeting will be scheduled at the end of fall quarter and all of the above must be presented. Also recommended: software architecture description document, preliminary design, use cases(iterative development process), weekly activity reports, and team member logbooks. [6]

At Washburn University, regardless of how a project is selected, the intent is to make one pass through the development life cycle. Deliverables include: project description, project plan, requirements and design specifications, data primitives such as records of hours worked on various tasks, code, and user manual. In all cases (including those for real customers), the final project is delivered without warranty and at best is considered a prototype. [8]

Carnegie Mellon expects a “designed, developed and test prototype” to be presented to the sponsor at the end of the 32 week period. [1]

University of Maryland’s iSchool allows for the sponsor to present a desired deliverable idea. The faculty works with the sponsor to finalize this idea.[9]

At La Salle University, students are graded on delivery of an outline, bibliography, first and final draft and a presentation to the class. [5]

At Harvard University, deliverables include a proposal as well as a series of business requirements and technical specifications, an implementation plan, as well as a final presentation based upon a written paper they students must complete. [4]

Student Assessment and Grading

There are variety methods for grading capstone project in different universities. For example, Dr. Greg Speegle from Baylor University believes “assigning a final grade to the project and then determining individual student participation is not reasonable given the team sizes. As a result, grades will be assigned on a bi-weekly basis according to the contribution of each student. The expectations for the following report period should always be clear, and the success or failure of a student to perform his assigned task should also be obvious.” [7]

At Seattle University, grading is the responsibility of the Faculty Advisor. Student performance should be assessed in terms of the purpose of the project, as identified above. Namely, does the team develop quality software in accordance with good design, development and, especially, management practices as described and learned in the Seattle University MSE program courses? Is a quality process used? Is all work accomplished in a professional manner? Are the project deliverables of high quality? Finally, is reporting and communication with the sponsor and with the advisor of a professional and informative manner? Grades are determined by assessing product, process, and professionalism. [6]

At Carnegie’s HCI Institute, grading is an overall process that is decided after the final stages of the project. The sponsor’s input, along with the involved
faculty, weigh heavily. Completion status and peer assessments conducted throughout the duration of the project are taken into account as well, however, the ultimate grading is determined by the satisfaction of and review from the sponsor in conjunction with the faculty overseeing the team’s progress. [1]

At the iSchool at the University of Maryland, the faculty in conjunction with the sponsor determine a feasible deliverable, and the students are graded, by the faculty, depending on how well they execute the sponsor’s desires. Peer assessment comes into play, but the faculty ultimately decide grading based upon the sponsor-expected deliverable, which for each project is of course very different depending on the industry and nature of the problem the sponsor is facing. [9]

At La Salle University, projects are reviewed by a team of readers appointed by the course director. Projects are presented to the review team in a presentation that is open to the public. Following the presentation the student must address issues raised by the review board and submit a final paper that addresses those issues. [5]

At Harvard University, students receive a group grade for the paper and presentation and individual grades based upon class contributions and a case analysis. [4]

Table 2: A sample project deliverables and grading criteria

<table>
<thead>
<tr>
<th>Guidelines</th>
<th>Grading Criteria</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status Report</td>
<td>Criteria</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Project Planning</td>
<td>Criteria</td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
</tr>
<tr>
<td>Requirements, Vision, Use cases</td>
<td>Criteria</td>
<td>30%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Design, Architecture, Rationale</td>
<td>Criteria</td>
<td>15%</td>
<td>25%</td>
<td>5%</td>
</tr>
<tr>
<td>Presentation</td>
<td>Criteria</td>
<td>25%</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>Text Plans</td>
<td>Criteria</td>
<td>5%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Delivery Documentation</td>
<td>Criteria</td>
<td>0%</td>
<td>0%</td>
<td>10%</td>
</tr>
<tr>
<td>Peer and Self Evaluation</td>
<td>N/A</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Research Plan/Experience Report</td>
<td>Criteria</td>
<td>0%</td>
<td>0%</td>
<td>10%</td>
</tr>
<tr>
<td>Advisor Evaluation</td>
<td>Criteria</td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 3: Grading scheme at University of Nevada

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (%)</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept</td>
<td>4</td>
<td>Description of project goals (minimum 1500 words).</td>
</tr>
<tr>
<td>Specifications</td>
<td>17</td>
<td>Software Requirements, Specifications Document.</td>
</tr>
<tr>
<td>Design</td>
<td>14</td>
<td>Design document with details of architecture, layout design, and test results design.</td>
</tr>
<tr>
<td>Implementation Integration and Testing</td>
<td>20</td>
<td>Document program code with details of program structure, model files, and test cases.</td>
</tr>
<tr>
<td>Presentation</td>
<td>8</td>
<td>Three presentations: overview, design, and final product (the first two during regular classes, the third in the project seminar Project Workshop).</td>
</tr>
<tr>
<td>Project Plan</td>
<td>8</td>
<td>Paper with project description, presented in the Workshop.</td>
</tr>
<tr>
<td>Project Thesis</td>
<td>4</td>
<td>Research project thesis submitted during project progress.</td>
</tr>
<tr>
<td>Course-related Exam</td>
<td>16</td>
<td>Test of UML and C++ knowledge as applied to individual projects (about 10% of the semester is project-related).</td>
</tr>
<tr>
<td>Participation</td>
<td>8</td>
<td>Participation in lectures and Workshop, GAI, community opportunities, peer evaluation, attendance.</td>
</tr>
</tbody>
</table>
Table 4: Student assessing (Grading) methods.

<table>
<thead>
<tr>
<th>Grading Parameter</th>
<th>Seattle</th>
<th>CMU</th>
<th>La Salle</th>
<th>Harvard</th>
<th>UofM</th>
<th>Baylor</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bi-Weekly report or similar</td>
<td>X</td>
<td>x</td>
<td></td>
<td>x</td>
<td>X</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Student self assessment</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midterm presentation</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Final presentation</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Technical document</td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Sponsor satisfaction and Other</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Real-World Project PROS and CONS

Benefits of the capstone courses are varied, but an examination of the benefits of a specific capstone can best demonstrate some of the potential contributions capstone courses can deliver. Some of the benefits for students are:

• Students will be well prepared for graduate studies and/or entry into the workplace
• Students will improve their advanced abilities and skills in solving computing problems
• Students will be able to culminate the key knowledge of the computer science curriculum and allow for the integration and reflection on previous knowledge
• Students will improve their abilities to convey technological information through written and oral communications and be able to keep abreast of technological developments on selected topics.

Teamwork the capstone course brings opportunities several times a week for colleagues to reflect on and discuss student learning in the major. Inevitably, such discussions include references to the curriculum, specific assignments, and teaching pedagogy.

Faculty have the opportunity to learn teaching strategies and discipline subfields from each other. This is a particularly good opportunity to mentor new faculty about the importance of discipline objectives, high expectations for students, and frequent faculty-

Local Industries and even universities department have opportunity to design, implement and maintain their projects by accessing to knowledgeable and fresh graduated students.

On the other hand, there have been concerns and issues related to a capstone course.

- Have standard approaches effectively promoted students learning experiences and reinforced their previous knowledge, as most capstone courses only address one or two subjects?
- Have the learning objectives of a capstone course met the various needs of career development goals for individual students? What are the quantitative measurements of student performance?

Answers to these questions are not always satisfactory. It is also noticed that a project-oriented capstone course is frequently loosely supervised. In addition, in many programs, there are other courses including team projects and software development, similar to that of a capstone, which makes it more difficult to differentiate exactly what the new benefits a capstone project can bring to the table.

Conclusion

In today’s rapid changing technological environment, capstone projects are necessary to bridge the chasm between university courses and real world computing problems to better prepare students to enter the work force. Often, a regular computing curriculum, while extremely information, is not enough to prepare students for what is in store upon graduating and applying for entry-level positions in the ‘real world’.

The capstone project ideology has the mission to elevate the entire cumulative curriculum into tangible, real-world skill sets. Of the participating universities, the methodology in administering, running, funding, and assessing each of these projects runs the gamut. Students, faculty and sponsors skill backgrounds also usually run the gamut, enhancing the interactive group experience. While many graduate level courses involve diversity in team work, the capstone usually involves an external sponsor to collaborate, which is what differentiates the capstone experience from a normal higher level graduate course.
Resources


[2] Sergiu M. Dascalu, Yaakov L. Varol,..., From Project Idea to Prototype Implementation, University of Nevada, reno, 35th ASEE/IEEE Frontiers in Education Conference, Indianapolis, IN, 2005


