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The Trend toward Online Project-Oriented Capstone Courses

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While at IBM, Professor Tappert adjuncted at North Carolina State University, SUNY Purchase, and Pace. He took-up teaching full-time when offered a position with the United States Military Academy at West Point. In 2000, after seven years at West Point, Professor Tappert accepted the position of Associate Program Chairperson for the Doctorate of Professional Studies in Computing here at Pace.

Professor Tappert's research interests include pattern recognition, biometrics, pen computing and voice applications, computer graphics, artificial intelligence, human-computer interaction, and e-commerce. Over the past five years, in conjunction with mentoring doctoral students and supplying projects for development teams in the MS in CS and MS in IT capstone courses, he has completed extensive investigation of the keystroke biometric for authentication and identification on long-text input.

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The Trend toward Online Project-Oriented Capstone Courses

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Abstract: At Pace University we have been using real-world student projects in capstone computing courses for about ten years. While the courses were conducted in a classroom environment during the early years, the current course has been essentially online for the last five years in order to reach a greater number of geographically scattered students. Findings indicate that appropriate team management changes can smooth the transition from collocated to distributed teams, and that peer evaluations and other remote assessment techniques make it possible to assess the work of students on distributed teams.

Keywords: distance education, online courses, capstone computing courses, project-oriented courses, collaborative and teamwork skills

Introduction

This paper concerns the pedagogical issues of managing information technology development projects conducted by geographically distributed student teams in an online course. We use team projects modeled on real-world development practice to provide students with the educational experience of collaborative efforts, similar to what is done in industry, in order to design, build, and test computer information systems.

We have been using real-world information technology projects in masters-level capstone computing courses for about ten years (Tappert, Stix, & Cha, 2007; Tappert & Stix, 2009a; Tappert & Stix, 2009b). Capstone courses that provide real-world projects for actual customers are not new. They are available in one or two-semester courses at both the graduate and undergraduate levels, and we briefly discuss several related papers from the recent literature. Novitzki (2001), in describing a one-semester graduate course, focused on the administrative issues and found that the most consistent shortcomings of the students related to their working with functional managers, their group skills, and their communication skills. Two papers (Gorka, Miller, & Howe, 2007; Green, 2003) described one-semester undergraduate courses that provided projects in conjunction with industry. Goold (2003) described how a one-semester undergraduate course evolved from small student teams of 4-5 students to relatively large teams of 10-12 students. Bruhn & Camp (2004) described a two-semester undergraduate course that required the full two semesters to provide an in-depth coverage of the phases of the systems development life cycle.

Beginning with the Fall 2006 semester, we migrated our highly successful, project-centered class from a traditional face-to-face format to an online format. Part of the reason was progressiveness – technical support for
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online courses had advanced to the point where it was reliable, fast, and offered excellent user interfaces, and online courses are preferred by our professionally employed student body because there are no scheduling conflicts, no missed contacts because of travel, and no commuting costs. In addition, we were readying ourselves for an expansion of the student body to students residing in different parts of the world. While we had found mechanisms for overcoming the challenges that threatened the effective governance and achievement of traditional student development teams, in 2006 we were confronting uncertainties about how these mechanisms port to teams working in the context of an online class and the new mechanisms that might need to be created. The online format precludes automatic, weekly assemblages that act as a safety net to the teams' interaction and smooth functioning. It is well known that projects undertaken by groups lacking co-presence presuppose a higher level of organizational and process skills among their members (Cusumano, 2008). This paper describes procedures that enabled the successful functioning of student development teams in a largely online course.

Another aspect of this course is the interplay of student projects and research done by students and/or faculty. One of the novel approaches we use to support student dissertation and faculty research is to create research-supporting projects in several of our courses. We teach our dissertation students how to conduct research in a number of areas of computing, and our student project teams how to develop real-world computer information systems. In recent years, we have experimented with the interplay of dissertation research and projects created specifically to develop the supporting software infrastructure for that research. Some of the project customers are faculty members or dissertation students who need supporting software infrastructures to conduct their research. Thus, there is interplay between the project and research activities.

The Project-Oriented Capstone Course

The current capstone course is a project-oriented, one-semester, web-assisted course for masters-level computing students in which student teams develop real-world computer information systems for actual customers. Students learn the importance of a systematic approach in the process of developing robust systems, the management of projects, how to interact with customers and conduct requirements analysis, how to build and test systems, and the related technical and soft skills. Emphasis is placed on developing skills and knowledge in technical areas that have practical value in the workplace. In addition to technical skills, students develop problem-solving, critical thinking, communication, and teamwork skills. By working on real-world systems with actual
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customers, the students learn the appropriate skills – both technical and soft skills – for filling meaningful roles in the professional IT workplace.

A capstone course is usually the last course taken in a program of study, in this case to complete the master’s degree requirements. Because the students have completed all the basic courses for their degree, they have a solid understanding of the fundamentals of computing and information technology and have acquired the studentship to fill in any gaps, as necessary, through self learning and independent study. This course enables them to draw on this knowledge and to apply what they have learned, and possibly learn some new material, to complete a real-world team project for an actual customer, similar to what most computing professionals do in their work environment. It is usually a great learning experience for the students and especially for those who have not previously worked on projects. We believe it lays the foundation for effective teamwork that Denning and Riehle (2009) find inadequate in many programs. Students have their team to work closely with, to give them support, and to learn from; and they also have access to the instructor and the class as a whole for further support.

Ingredients for Successful Teamwork in Distance Learning

Although this is essentially an online course, we have three face-to-face meetings in a classroom during the semester: one near the beginning, one near the middle, and one at the end of the semester. These contacts, presence at which is highly recommended but not required, are typically attended by about two-thirds of the students – those who live or work in the greater New York City area. The first contact is important because it introduces communication standards and the archiving of course information. An extensive course website presents all the course information, with links in the left menu area providing access to the sections (pages) of the website:

- Homepage – includes the instructor information, textbooks, course description and goals, course requirements, and grading system.
- Syllabus – lists the weekly readings and assignments.
- Projects – contains a table of the semester’s projects, and provides for each project the customer’s name and contact information, the description of the project, the names of the students on the development team assigned to the project, and a link to the project team’s website.
- Students – contains photos of the students so students know their classmates and the instructor can recall a student (possibly years later) when providing a letter of recommendation.
- Project Deliver – lists and describes the project deliverables.
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- Grades – contains a table of the graded events and the current student grades indexed by the last 4 digits of their university ID number.

- A link to the Blackboard educational software system (Blackboard, 2010) used for quizzes, discussions, and collecting digital assignments.

The instructors solicit and interact with potential customers to set up new projects, work with the university computer support personnel to assure the presence of the required project development software and computing infrastructure, and monitor the systems' development process. Projects come from faculty and dissertation students interested in developing systems to further their research, from other departments or schools of the university needing computer information systems, from non-profit community institutions such as local hospitals, from local research institutions, and from interests of the project students. The instructor sizes and shapes each project to be an appropriate systems development experience for the students, forms the student teams, and assigns each team to a project.

From the project descriptions posted on the course website the students complete a project preference form during the first two weeks of the course. They list their current company and job title, number of years of work experience in information technology, work and home locations, whether they can attend the three classroom meetings, preferred communication mode (email, phone, IM, etc.), top five project choices, top five availability time choices for project communication (day of week plus morning, afternoon, or evening), project skills (requirements engineering, system design, programming, databases, web design, networking, communication/leadership, etc.). The instructor uses this information to form teams, to select team leaders, and to assign teams to projects.

Nature of the Team Projects – Categories and Examples

The team project focuses on developing a computer information system that meets an actual customer's real needs. Although the requirements for the projects come from the customers, the course instructor is the "boss" or "Chief Information Officer" of each project team, and, as such, the person who makes all the major decisions. The project customer knows what he/she wants as an outcome but may not know the technical aspects of the project work (algorithms, program code, etc.). Some projects have subject matter experts who are knowledgeable about certain domain related aspects of a project. The customer, the subject matter experts, and the instructor can give advice to help guide the teamwork but are not expected to make major contributions to the actual project development effort.
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To inform the readers of the types of projects conducted, we present a tabular summarization of 63 projects resulting in 132 publications, as summarized in Table 1, with project sources in Table 2, publication outlets in Table 3, and project descriptive titles in Table 4. All of the 63 projects were in masters-level courses except for 4 in undergraduate courses. All of the masters-level courses had the project as the centerpiece, with 52 of these 59 masters-level projects in the capstone courses, "Software Engineering" and "Capstone Project." The remaining 7 were in a "Pervasive Computing" elective. Of the 132 resulting publications, 94 were directly project-related, and 38 were similar in kind and designated "offshoot publications" (Table 1).

Because many of the projects were continued, often with a different emphasis, by different student teams in successive courses and because some of the student and faculty research was conducted without supporting projects, the project and research work, in seven broad categories, fall into the 44 titular groups shown in Table 4. Each project was conducted by a student team. The 63 teams consisted of a total of 183 students, resulting in an average team size of roughly three students per team.

<table>
<thead>
<tr>
<th>Project Category</th>
<th>Number Projects</th>
<th>Project Semesters</th>
<th>Project Related Pubs</th>
<th>Offshoot Pubs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web Applications</td>
<td>8</td>
<td>12</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Pervasive Systems</td>
<td>14</td>
<td>24</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>PC Applications</td>
<td>10</td>
<td>17</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Artificial Intelligence</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Pattern Recognition</td>
<td>8</td>
<td>11</td>
<td>27</td>
<td>19</td>
</tr>
<tr>
<td>Biometric Systems</td>
<td>12</td>
<td>15</td>
<td>17</td>
<td>19</td>
</tr>
<tr>
<td>Quality Assurance</td>
<td>5</td>
<td>9</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>63</td>
<td>96</td>
<td>94</td>
<td>38</td>
</tr>
</tbody>
</table>

Table 2. Project sources.

<table>
<thead>
<tr>
<th>Project Source</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faculty Ideas or Research</td>
<td>32</td>
</tr>
<tr>
<td>Student Ideas or Research</td>
<td>13</td>
</tr>
<tr>
<td>External Community</td>
<td>10</td>
</tr>
<tr>
<td>Internal University Needs</td>
<td>8</td>
</tr>
<tr>
<td>Totals</td>
<td>63</td>
</tr>
</tbody>
</table>

Table 3. Publication types.

<table>
<thead>
<tr>
<th>Publication Type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Conference Papers</td>
<td>48</td>
</tr>
<tr>
<td>Journal Articles</td>
<td>4</td>
</tr>
<tr>
<td>Book Chapters</td>
<td>1</td>
</tr>
<tr>
<td>Doctoral Dissertations</td>
<td>15</td>
</tr>
<tr>
<td>Masters Theses</td>
<td>3</td>
</tr>
<tr>
<td>Internal Conference Papers</td>
<td>57</td>
</tr>
<tr>
<td>Internal Technical Reports</td>
<td>4</td>
</tr>
<tr>
<td>Totals</td>
<td>132</td>
</tr>
</tbody>
</table>
## Table 4. Project and research group details, with the research groups indicated by *.

<table>
<thead>
<tr>
<th>Category</th>
<th>Project Group</th>
<th>Number Projects</th>
<th>Project Semesters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web App</td>
<td>Online Course Opinion Survey System</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Web App</td>
<td>Genealogy Web Application</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Web App</td>
<td>Automated Complaint Desk System</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Web App</td>
<td>Rockefeller State Park Information Website</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Web App</td>
<td>Pace Weather Information and Web Database System</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Web App</td>
<td>Online Patient Medical Data Entry System</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Pervasive</td>
<td>VoiceXML Development Facility and Applications</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Pervasive</td>
<td>Multimodal Voice/InkXML System</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Pervasive</td>
<td>PC Maintenance/Tracking System</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Pervasive</td>
<td>Emergency Pre-Hospital Care Communication System</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pervasive</td>
<td>Medical Vital Sign Wearable Computer System</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pervasive</td>
<td>Hospice Nurse Telemedicine System</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>PC App</td>
<td>Cluster and Grid Computing Systems</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>PC App</td>
<td>Test Item Reliability Analysis System</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>PC App</td>
<td>Set of NLP Algorithms for Teaching/Research</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>PC App</td>
<td>Pitch Training System for Western and Eastern Music</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>PC App</td>
<td>Automated XML Teaching System</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>PC App</td>
<td>Astronomy Image Database and Retrieval System</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>PC App</td>
<td>Reengineered Antique Business Filing System</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>PC App</td>
<td>Depth-wise Hashing Structure</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>AI</td>
<td>Project Group Assignment System</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>AI</td>
<td>AI Optimizing Bridge Bidding Website System</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>AI</td>
<td>Human Brain Systems’ Neural Network and Hawkins</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>AI</td>
<td>Mixed-Reality Pocket Billiards System</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Pattern Reco</td>
<td>Interactive Visual System – Rare Coin Grading System</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Pattern Reco</td>
<td>Interactive Visual System – Flower Identification App</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Pattern Reco</td>
<td>Interactive Visual System – Flag Identification App</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pattern Reco</td>
<td>Interactive Visual Systems – Pottery, Painting, etc.</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Pattern Reco</td>
<td>Shorthand Handwriting Recognition System</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pattern Reco</td>
<td>Spam Detection System</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pattern Reco</td>
<td>Automatic Language Detection of Text Files</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pattern Reco</td>
<td>Handwriting Forgery Quiz System</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Pattern Reco</td>
<td>Visual Systems, Theoretical Studies, etc.</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Biometric</td>
<td>Multimodal User Verification System</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Biometric</td>
<td>Eigenface Recognition System</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Biometric</td>
<td>Voice Authentication Biometric System</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Biometric</td>
<td>Pronunciation Biometric System</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Biometric</td>
<td>Keystroke Biometric System</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Biometric</td>
<td>Mouse Movement Biometric System</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Biometric</td>
<td>Stylometry System</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Biometric</td>
<td>Iris, Handwriting Style, and Other Biometric Systems</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Biometric</td>
<td>Theoretical and Other Studies</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>OA</td>
<td>Quality Assurance/Maintenance Tools</td>
<td>5</td>
<td>9</td>
</tr>
</tbody>
</table>

In the fall of 2009 we had ten projects as shown on the Projects page of the course website (Figure 1). It was unusual this semester that most of the project customers were doctoral students enrolled in our Doctor of Professional Studies (DPS) program. The Projects page lists the projects and contains, for each project, the project ID number, the project customer(s) with links to detailed contact information, a link to a detailed project description (and whether the project is a continuation of an earlier one), and the student team (marking the team leader). The
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project ID number is also a link to the student team website for the project. The team website for the “Keystroke Biometric: ROC Experiments” project is shown in Figure 2.

Two projects will be briefly described, one from spring 2009 and one from fall 2009. The spring project, entitled “Personality Assessment from Handwriting,” involves the Lewinson-Zubin (L-Z) scales, scientific handwriting analysis scales proposed by Thea Stein Lewinson and Joseph Zubin, which have been used in handwriting analysis over the last half century (Lewinson & Zubin, 1944). One of the vexing problems of these scales is the time it takes for handwriting analysts to measure the L-Z scales. The goal of this project was to develop a computer assisted L-Z scale extraction system for the purpose of handwriting analysis. Most scales can be automatically and objectively extracted once documents are optically scanned, and a graphical user interface allows handwriting analysts to extract most L-Z scales more efficiently and objectively. What has been classified information until the recent publication of a book on spycraft (Wallace, Melton, & Schlesinger, 2008) is the fact that Lewinson worked for the CIA for eighteen years as a graphologist, and that the CIA used graphology for operations, in particular to assist operations officers in identifying potential targets for double agents.

A continuing line of research, and one that brought forth many projects, is on the keystroke biometric, one of the less-studied behavioral biometrics. The fall project, entitled “Keystroke Biometric: ROC Experiments,” extends the previous work. Keystroke biometric systems measure typing characteristics believed to be unique to an individual and difficult to duplicate. Over the last five years, we have developed at Pace University long-text-input keystroke biometric systems for identification (one-of-n response) and for authentication (accept/reject response). In this keystroke biometric area we have had about ten semesters of masters-level project work, three doctoral dissertations, three external conference papers, a book chapter, and a journal article recently accepted for publication (Tappert, Cha, Villani & Zack, 2010). The focus of the fall project was on further developing the authentication system, especially developing Receiver Operating Characteristic (ROC) curves, and conducting additional experiments.
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Figure 1. The “Projects” page of the course website for fall 2009.

Keystroke Biometric: ROC Experiments

Team 3

Keystroke biometric systems measure typing characteristics believed to be unique to an individual and difficult to duplicate. There are two commercial products currently used for hardening passwords (about 20%) in existing computer security schemes. The keystroke biometric is one of the least-studied biometrics, researchers tend to collect their own data and no known studies have compared identification techniques on a common dataset. Nevertheless, the published literature is optimistic about the potential of keystroke dynamics to enhance computer security and usability.

Home
Project Status
Deliverables
Deliverables 2009
Technical Paper
Presentations
Minutes of Meetings
Team Members
Contact Us
2009 Work

The keystroke biometric has several possible applications. One application is to identify or isolate from biometric pattern (one-off response). Suppose, for example, there has been a problem with the circulation of documents from easily accessible desktops in a work environment. The security department wants to reduce the problem by collecting keystroke biometric data from all employees and developing a keystroke biometric identification system.

A second application is authentication process. Identity verification is performed, yes, are you the person you claim to be or are you not? For example, password entry could be "hardened" by adding as a keystroke authentication process at

Figure 2. Team website for the “Keystroke Biometric: Refactor System & Conduct Experiments” project.
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Nature of the Teams, Their Roles, and Methods of Work

A team is a group of individuals having the responsibility to jointly accomplish an objective, and in this course the objective is to successfully complete a project. Research has shown that work in teams enhances learning by creating an "active learning process." Student teams have been found particularly effective when the students actually need each other to complete the project. It is also the norm for employees to work in teams, and teams are used in all kinds of organizations, such as in industry, education, and government.

Most of the systems involve one or more of the following: programming, a database, a computer network, a Web interface. Java is the preferred language for projects that require programming. Non-programmers or weak programmers can contribute in many ways other than programming. A team usually consists of 3-5 students – an Architect-Designer, one or two Implementers, a Quality Officer, and a team Coordinator-Liaison. For small teams several team member functions can be combined. At least one team member, usually the Coordinator-Liaison, must be a good communicator for customer and instructor interactions. Once the project is underway, teams should interact at least once a week in addition to project work time, and interactions can be through a variety of communication modes, such as e-mail, online discussion, comments affixed to work-related materials, chat, and face-to-face.

For project development work we use the agile methodology, particularly Extreme Programming (XP) which involves small releases and fast turnarounds in roughly two-week iterations (Beck, 2000). Each team delivers a prototype system that performs the basic required functions to their customer at the halfway point of the semester. This is possible since, according to the 80-20 rule (Pressman, 2010), 80% of the project can be completed in 20% of the time it would take to deliver the complete system. A complete system is delivered at the end of the semester.

Student/Faculty Research

The Doctor of Professional Studies in Computing program enables computing and information technology professionals to earn a doctorate in three years through part-time study while continuing in their professional careers (Merritt et al 2004, Grossman et al 2010). In contrast to project work which uses known technology to develop systems according to specified customer requirements, research is original, rigorous work that advances knowledge, improves professional practice, and/or contributes to the understanding of a subject. To graduate, each doctoral student is required to complete an original investigation presented as a dissertation. The masters-level thesis also gives students the option performing research and completing a dissertation during their last year of studies.
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Research methods depend upon the nature of the inquiry: controlled experiment, empirical studies, theoretical analyses, or other methods as appropriate. We require research work to be of sufficient strength to be able to distill from it a paper worthy of publication in a refereed journal or conference proceedings.

For dissertation work at the doctoral and masters levels we introduce the student to the research process. In our doctoral program the students' first step is to select a suitable research area. We highly recommend that they choose an area of research in which they have extensive knowledge and preferably expertise. For the doctoral students this is possible because they must be seasoned computing professionals with a minimum of five years experience in industry to enter the program. Compared to traditional doctoral programs, into which many students matriculate directly from their undergraduate/masters-degree school and have to come up to speed in their research area, this alone can save several years of effort. The second step is to select a suitable research problem. This and most of the following steps are accomplished through an agile evolutionary process of independent work by the student, interactions with the student's advisor, and presentations and discussions in research seminars with active participation of faculty and classmates. Most importantly, the students are encouraged to choose an area of research and a problem about which they are enthusiastic. The third step is to review of the literature. Similar to the traditional dissertation approach, each student independently reviews the literature relevant to their problem. In our doctoral program, however, the students must then present their literature review in the context of an idea paper which is a brief (agile) version of the traditional research proposal. The idea paper is scrutinized and typically undergoes revision through the agile evolutionary process of presentations and discussions in research seminars. During the evolution of the idea paper the student chooses an advisor and committee. The fourth step is to develop an increasingly detailed investigation plan which is incorporated into the idea paper as a growing working document. The fifth step is to conduct the research which is done with frequent interactions (weekly recommended) with the student's advisor. During the third year, when the students are engaged in their research and no longer taking classes, we conduct Saturday dissertation status sessions, three per semester, where the usual student presentation format is a brief "elevator-ride" description of one's research problem, what was done since the last session, what is currently being done, and what will be done by the next session. The final step is completing the writing of the dissertation. Although we listed the steps sequentially, this is an evolutionary process that typically has several iterations, with backtracking and restarts, and the process is different for each student. However, in each
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case the idea paper, begun early in the process, is expanded into an end-to-end document and continually developed until it eventually becomes the dissertation.

The agile dissertation process, which incorporates high levels of peer involvement and faculty mentoring, is special to our program. Similar to software development work, we use the agile methodology throughout the dissertation process. In particular, we use the Extreme Programming (XP) method of small releases and fast turnarounds in roughly two-week iterations to make incremental advances. For software, the hallmarks of agile methodology are starting small (with the simplest thing that can work), incremental releases, and constant testing (and completed tasks are highly valued). The dissertation process starting with a small idea paper, entails its incremental development, and requires successive drafts to be presented for review to peers and/or the advisor.

Doctoral students' classmates, the cohort group, contribute frequently by making helpful suggestions in the meetings and by helping to find relevant literature and related material. This is an important part of the agile dissertation process and all students are expected to participate and help their colleagues. The power of the community is strong. Beginning in the second year we use the Socratic method of clarification through confrontational dialogue. This forces students to think for themselves and to vigorously defend their position. Because this method works best when the student is adequately prepared, the student is strongly advised to put substantial effort and thinking into his/her preparation for the group sessions. We find that the better the student is prepared, the more the student benefits from these interactions. From the Wikipedia the Socratic Method is, "...asking a series of questions surrounding a central issue, and answering questions of the others involved. Generally this involves the defense of one point of view against another and is oppositional."

We also emphasize writing, and we do this for several reasons. First, only by expressing their ideas in writing do students get a good grasp on them. Second, the written form of ideas is easily amenable to iterative refinement which we recommend. Third, this is the best way for a student to communicate their ideas with their advisor and discuss them point by point. In addition, we recommend that students maintain a dissertation notebook as a repository of ideas, thoughts, and data – the only place that they write, diagram, or doodle about their dissertation. We also recommend, usually to get a student focused, the submission of a paper for conference presentation while dissertation work is still underway.
Benefits of the Research and Project Activity Interplay

There are many benefits of the research and project activities. The real-world projects provide valuable systems for the customers, allow the students to develop technical and value skills, utilize student-centered team learning, foster interdisciplinary collaboration, encourage student involvement in the university and local communities, support student and faculty research, and enhance relationships between the university and local technology companies. Overall, these projects result in a beneficial outcome for all concerned.

The research students learn the required individual skills necessary to conduct a research study. They learn how to perform literature searches to gain general knowledge about an area and to determine what previous work has been done on a specific problem. They learn organizational and critical thinking skills, how to be innovative and creative, and how to structure and perform their research studies. By serving as a customer of a student project that develops supporting infrastructure for them, they learn important management and leadership skills. Finally, in writing their dissertations they learn how to set their research in a proper context, to describe their methodology and findings, and to estimate its potential impact.

For the project students as individual technologists, as team members, and as maturing computing professionals, developing real-world systems for actual customers is a stellar real-world learning experience. Individually, the students learn the technology skills necessary to develop real-world computer information systems. Students learn the importance of a systematic approach in the process of developing robust systems, the management of projects, how to interact with customers and conduct requirements analysis, and the associated soft skills. Emphasis is placed on developing skills and knowledge in technical areas that have realistic value in the workplace. Through project reviews and team presentations, the students also learn about the various technologies used in the other projects, and they especially appreciate the exposure to projects involving cutting-edge technology and research. Working in teams, the students learn fair-mindedness, intellectual humility, intellectual integrity, and the ability to work with others to produce useful systems and to take responsibility for them. Because most of the students are employed full time in various areas of computing, they bring their knowledge and expertise to bear in their project work, and by exchanging information they learn from each other in this student-centered learning environment. As maturing professionals, the students learn how to act in the computing field not only as technologists but also as value providers. By working with real customers in developing their project systems and
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focusing on human-centered computing, the students learn important value skills (Denning & Dunham 2001). This learning paradigm fosters lifelong habits for learning and the application of critical thinking and value skills.

A side benefit is the presentation and publication activities that enhance communication skills. We have both the research and project students produce papers for publication, which is a novel aspect of our teaching approach. For the dissertation student we encourage publication, even if only for an internal conference or workshop, soon after the student obtains preliminary results. We have established a yearly internal conference complete with a review process and proceedings, for this purpose. We have found this helpful because it is much easier to begin by writing a small paper than a large dissertation, it solidifies the problem statement and general approach with some preliminary results, it ensures that the student and advisor have a common understanding of the problem and methodology and that the advisor buys into the process, and it generates ideas and motivation for extending the work into a significant research study acceptable as a dissertation. One of the key project deliverables is a technical paper that summarizes the results of the project and is presented at our yearly internal conference which is complete with a review process and proceedings. We have found that working to produce publications is a strong motivating factor for the students. The publications also enhance the external image and identity of our programs.

The various customers benefit from the systems created for them by the students, sometimes receiving systems they might not obtain under ordinary circumstances. The primary inducement for the customers’ involvement with the student team is the anticipation of receiving a useful system, although they are warned that the chief purpose of the projects is to provide the students with a good educational experience and that not all projects are successfully completed. The customers include the research students, the faculty, the internal and greater university communities, and the community non-profit and technology organizations. In some cases, this amounts to a monetary savings, because the customers do not have to outsource the projects. The university itself benefits by having small projects completed by students.

The projects promote interdisciplinary collaboration and university and local community involvement. The projects involve two communities: the university community and the local community external to the university. Within the university community, many of the projects involve interdisciplinary collaboration with other departments, such as the medical projects with the nursing school, the online survey project with the assessment department, and the involvement with the business school and the department of information technology. The work with other universities, such as the Rensselaer Polytechnic Institute, extends our collaboration to the greater
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university community. The projects also extend into the local community, involving three local hospitals, the IBM speech and pen computing groups, and a small company, to provide the students with off-campus experiences and to foster an extended community for learning and growth. Because project customers come from the local community as well as from the university community, the project work brings to light how knowledge of computing and information technology connects with personal and social responsibility.

Geographically Distributed Student Teams

Currently about two-thirds of the students live or work in the greater NYC area. The remaining third come mostly from more distant regions of the east coast but some have been from as far away as California, Europe, and Asia, with a group of 15 students from India in the fall of 2009. The distributed team issue is handled by a number of mechanisms and guidelines.

To facilitate communication among the project stakeholders, we insist that, except for extenuating circumstances, communication between a team and instructor, and between a team and a customer, be through the team leader, with all team members copied on communication email and given summaries of face-to-face meetings. This reduces communication to the instructor from individual students and keeps all stakeholders updated on project activities. Although we had the same guideline when the course was conducted in the classroom with local students, this guideline is even more critical for distributed teams. Also, the instructor creates and uses email distribution lists for the whole class, for each project team including the customer, and for all the customers.

Project team leaders must be local, either living or working in the greater NYC area. This allows for easy communication and meetings between the project team leaders and the project customers, who have, so far, all been local. It also allows for similar contact between the project team leaders and the instructor, enabling the instructor to keep informed of the progress of the project work.

The course website efficiently presents all the course information as described above for convenient centralized access. Most importantly, it contains the project-related information and links to the student-developed team project websites that are frequently updated with postings of project deliverables and other information. To ensure that the students read and understand the material on the course website, the first quiz contains questions on the course operation as described in the website material.
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The three 3.5-hour classroom meetings are important to bring the local students together so they can meet many of their teammates and form some face-to-face bonding. The first meeting occurs after the first week of the semester. By this time:

- the students have introduced themselves online through a Blackboard forum, reviewed the course website, and submitted the project preference information form to the instructor
- the instructor has received the students' project preferences and associated information, formed the student project teams, assigned teams to projects, chosen project team leaders, and posted the information on the project's page of the course website

At this meeting the instructor and students introduce themselves face-to-face (half hour), the instructor gives a lecture on the nature and value of conducting real-world projects in a capstone course (one hour), the instructor reviews the specifics of the course material and describes each of the projects (one hour), and the students group themselves into their project teams and begin planning project activities (one hour). Some customers attend the first meeting to introduce themselves and to meet the members of their team.

At the second (midterm) meeting the students make PowerPoint slide presentations of their project prototypes (20-30 minutes per team depending on the number of projects – there were five projects in spring 2009 with 4-5 students per team). Material covered in these presentations includes, as appropriate and as time permits, a subset of the following items: brief description of project, summary of project specifications, frequency of meetings with customer/stake-holders and usual method of communication, plans to address changes in customer requirements, summary of user stories collected (if any), analyses accomplished (object-oriented might include defined classes and operations), design decisions and the trade-offs encountered, work breakdown structures, PERT chart, and/or Gantt chart, components built/planned, testing strategy, what was accomplished to complete the prototype, what will be added in the remainder of the semester, what has been easy/difficult during this half of the semester, and a prototype demonstration. Many customers attend the second meeting.

At the third (semester-end) meeting the students present their final project system. This meeting is similar to the second meeting, and most of the customers attend the final presentations.

**Student Assessment**

Student assessment is currently as follows: individual quizzes (20%), initial team assignment (10%), team project midterm (20%), team project final (20%), and team project technical paper (30%). Thus, 80% of a student’s
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grade is based on their contribution to the team effort with the quizzes (based primarily on the textbook material) providing the only direct individual assessment. Mid-term and final exams used in a previous two-semester course were eliminated allowing the students to focus on the project work in this one-semester course. The initial team assignment, which is not related to the project and due early in the semester (after three weeks), provides the context for the students to learn to function as a team. The team has the ultimate responsibility for the project work and is graded accordingly. Grades on team events are determined by first assigning a team grade and then adjusting an individual student’s grade up or down based on evaluations of the student’s contribution from the instructor, the project’s customer(s), and the student’s teammates.

Since this is a project-oriented course with no midterm or final exams, student grades depend mostly on their contribution to the project work. The usual expected time commitment per student for a 3-credit course is 3 hours per week in class and twice that outside of class, for a total of 9 hour per week. However, because this is an online course where students save commuting time, we expect a time commitment of about 10 hours per week, and this additional time commitment is one of the advantages of a distance-learning course.

Blackboard Educational Software

The Blackboard educational software system (Blackboard, 2010) is used for quizzes, for collecting digital deliverables, and for discussion forums. There are discussion forums for archiving all instructor email to the whole class for easy reference, for student introductions (students are asked to introduce themselves online during the first week of the semester), for discussions related to the textbook and other course material, and for discussions relating to each of the projects. The project forums are used to discuss project-related material, and each project team is required to post a weekly project status report on their project forum. It might be mentioned that previously student teams gave their status reports verbally in the classroom and students could benefit by learning about the other projects and hearing the instructor feedback, whereas now they are posted on the project forums (and simultaneously on project websites) where they are less likely to be reviewed by students in other projects.

Self and Peer Evaluations

Finally, we use peer evaluations to assess the project contributions of each team member. Although used when the course was conducted in the classroom, peer evaluations are even more critical for distributed teams because some team members have minimal, if any, direct contact with the customer and instructor. Obtaining individual student grades on teamwork has been reported in the literature. For example, Clark, Davies, & Skeers
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(2005) created an elaborate web-based system to record and track self and peer evaluations, Brown (1995) has a system similar to ours but which uses more granular numerical input, and Wilkins & Lawhead (2000) use survey instruments.

The students are required to provide self and peer evaluations three times during the semester – once after the initial assignment primarily to acquaint the students with the process, at the midterm checkpoint, and at the end-of-term checkpoint. They evaluate each team member, including themselves, by assigning “=" for average contribution, “+” for above average contribution, and “-" for below average contribution. Multiple “+" or “-” signs can be used to indicate extra strong or extra weak contributions, but the total number of plus and minus signs must balance out (i.e., be equal in number). A team grade for a particular deliverable or time interval is first determined, and then grades for individual students are adjusted relative to the team grade based on the peer evaluations along with additional input from the customers and instructor. For example, a typical peer evaluation summary chart with associated grades is shown in Table 5 for a four-member team. Each of the four evaluation columns shows the evaluation of a team member evaluating him/herself and the other team members. The summary column shows the sum of each row of evaluations, and the grade column shows the student grades. Here, a team grade of 85% is first determined and then individual grades are adjusted relative to the team grade, in this case up or down 2% for each “+” or “-” sign. For simplicity, this table shows only the peer evaluations, but customer and instructor evaluations are usually included as well. Team leader and instructor evaluations can be given extra weight, and self evaluations that appear overly inflated are usually eliminated.

Table 5. Example team peer evaluation and grade chart.

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Eval 1</th>
<th>Eval 2</th>
<th>Eval 3</th>
<th>Eval 4</th>
<th>Summary</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+</td>
<td>=</td>
<td>+</td>
<td>++</td>
<td>+ + +</td>
<td>93</td>
</tr>
<tr>
<td>2</td>
<td>=</td>
<td>=</td>
<td>-</td>
<td>- -</td>
<td>= - -</td>
<td>79</td>
</tr>
<tr>
<td>3</td>
<td>=</td>
<td>=</td>
<td>+</td>
<td>-</td>
<td>= - -</td>
<td>83</td>
</tr>
<tr>
<td>4</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>+</td>
<td>= -</td>
<td>85</td>
</tr>
<tr>
<td>Average</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>= -</td>
<td>85</td>
</tr>
</tbody>
</table>

Students are also asked a number of general questions for the time interval in question – the number of hours per week spent on project work, their specific contributions, their strengths and how these were used, their areas needing improvement, and what has enhanced and/or handicapped their team’s performance – and the responses might influence the instructor evaluation of a student’s contribution to the team effort. For additional input the instructor can discuss team member contributions with the team leader.
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Customer Evaluations

At the end of the semester we survey the students using the Survey Monkey (2010) web-based survey system to obtain feedback on the team-customer interactions during the semester: whether the customer's initial project specifications were clear and understood, whether the amount of contact/interaction was adequate, whether the speed of response to questions was adequate, and whether the continued guidance and direction on the project work was sufficient. This information is used to determine the team satisfaction with a customer and, for example, whether to continue or not continue a project with a particular customer.

Pedagogical Evaluations

At the end of the semester we survey the students to obtain feedback on the course methodologies and procedures, such as what has worked well or not well from the students' point of view. We use these pedagogical evaluations to change our methodologies and procedures from time to time, and to keep informed on the technologies and methodologies the student teams are using. We find, for example, that student teams use many modes of communication, and one of the interesting ones recently reported was Skype (Skype, 2010).

Conclusions

The online course format necessarily means a reduction in the face-to-face contact time of student teams jointly working on projects inasmuch as weekly class assemblages no longer exit. All courses with a collaborative component requiring groups to complete a task requiring cooperation and coordination over an extended time will find that the students are forced into working in a distributed context. For projects' success, and therefore course success, effective techniques for managing distributed student teams are required. We confronted this pedagogical issue head on in a masters-level, capstone course in which teams of students in computer science and internet technology develop real-world systems for actual customers. This course had been in successful operation for over five years in the face-to-face mode when it shifted to online. Here we experienced success as well.

Our success in the online mode rests on much of the same management infrastructure that had facilitated effective communications among "traditional teams," notably the website that comprehensively centralized access to project information and Blackboard for organizing digital deliverables and discussion forums. The new pedagogy consists of an initial face-to-face contact offering a rigorous introduction to the usage of the information dispensing and communication channels, the requirement that the team leader live locally and be amenable to in-person meetings with the customer and the instructor, and rigid requirements about circulating communications and
We have also found an exciting and productive interplay between research and project activities. The main benefits have been to increase faculty research productivity, to facilitate the completion of the doctorate program for gainfully employed information technologists, and to strengthen capstone classes in the masters program. The mechanism has been using research to provide projects, and using projects to supply computing infrastructure. We term this symbiotic relationship the research/project interplay.

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