A Decade Review of a Masters-Level Real-World-Projects Capstone Course

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Abstract

Our mission of capstone computing courses for the past ten years has been to offer students experience with the development of real-world information technology projects. This experience has included both the hard and soft skills required for the work they could expect as industrial practitioners. Hard skills entail extending one's knowledge structure with technical know-how, specifically using the latest software and hardware tools for building applications of genuine utility. Soft skills include the ability to work in a collaborative setting (e.g., to participate in team coordination and governance), the ability to interact with a customer (e.g., to establish product requirements and achieve acceptance), the ethos of creating value, and a facility for technical communications (written, oral, and electronic). Significant changes in the instructional environment have taken place in the ten years since the capstone class was first offered. This paper describes the adaptation to changes in the course's delivery so that its mission continues to be fulfilled successfully.

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

1. INTRODUCTION

The aim of our capstone is to familiarize students with how their trade is plied in organizations, so that the masters program delivers "the practice" part of the promised "theory and practice." The projects are "real world" in every respect. They entail the development of an application desired by a real world customer. As in industry, applications are developed by a small, collaborative team which needs to communicate with the customer, coordinate its activity, attend to internal decision-making, and, as observed by Denning and Dunham (2001), be sensitive to delivering value. The applications press into service current technology. This is technology with which the students are usually unacquainted inasmuch as it may be specialized, new, or at least new to them. Students learn about real-world technology through their own group's experiences well as through reports from other groups. A soft skill of transcending importance, emphasized by activities throughout the capstone, is the ability to communicate on technical concepts and issues; orally, in written reports, and via Web media; to peers and lay people.

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. 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. A series of papers has described real-world information technology projects in masters-level capstone computing courses (Tappert & Cha, 2004; Tappert, Stix, & Cha, 2007; Tappert & Stix, 2009; Tappert & Stix, 2011).

In the ten years since the capstone class assumed its project-based form the most significant change has been in its presentation. In 2001-2002 the class spanned the fall and spring semesters and was face-to-face. In 2006 it was condensed into a one semester offering. For projects, this meant that requirements elicitation, building the application, and the testing regimen were accelerated. We responded with agile methodology. In 2006 the class's delivery also shifted from face-to-face to "hybrid": online but with a meeting at the beginning of the semester for orientation, a meeting at the middle of the semester for team reports to the class, and a meeting at the end of the semester for final system presentation. By 2009 the format was entirely online for portions of the class for whom attendance was geographically infeasible. This included 15 students taking the class from India.

What has not changed over time is the essence of the course. Groups are still required to maintain a Website for project tracking, have a single spokesperson for interacting with the customer, and attend to the division of labor. Projects must still be delivered. And a professional paper, about the project, must still be written by the group and presented at our annual internal conference that provides students and faculty with the opportunity to present their research and project work.

The remainder of this report goes into the details of each aspect of the course touched upon above. It explains how the course is currently managed and presents a compressive review of the projects completed over the past ten years.

2. TEAM-ORIENTED CAPSTONE 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 also discuss the pedagogical issues of managing information technology development projects conducted by geographically distributed student teams in an online course.

Effective teamwork requires the division of responsibility, the coordination of efforts, communications to expedite coordination, and group governance for collective decision making, conflict resolution, and the control of deviance. Denning and Reihle (2009) draw attention to both the importance of group dynamics to software engineering and the traditional failure to accord them proper regard in project development courses. To pique the interest of students in "teamwork dexterity," which is even more critical to the functioning of distributed teams, we are capitalizing upon their enthusiasm for the television reality game shows such as *Survivor* and *The Apprentice*. Individuals in groups (tribes or teams) on these reality shows, as in the course, are: working toward common goals; acquiring and sharing new knowledge about the problem, the solution, and cooperative processes; harnessing the different skills of the different teammates; adjusting to the different personalities of the different teammates; exhibiting initiative but without disruptiveness; and learning to shoulder group obligations responsibly. The settings differ in significant interpersonal ways as well. For example, our project students don't get eliminated from the course, as participants can be eliminated from the game shows – like "voted out" on *Survivor* or "you're fired" on *The Apprentice*. Other differences are that reality show participants compete against each other, competitiveness is encouraged, and devious behavior on the part of participants against other participants is accepted as part of the game.

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. 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.

As the ability for impromptu team discussions before and after class disappeared and online communication became dominant, the internal dynamics of the development teams became more complicated. In addition, we needed to revisit the way we graded the performance of team members (see section 6).

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.

3. 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 customers, the students learn the appropriate skills – both technical and soft skills – for filling meaningful roles in the professional IT workplace.

Team Project Categories and Publications

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.

Table 1 presents the 102 projects conducted over the last ten years together with the resulting 185 publications. Table 2 lists the project sources, Table 3 the publication categories, and the Appendix provides a detailed list of the publications. Of the 185 resulting publications, 142 were directly project-related, and 43 were similar in kind and designated "offshoot publications" (Table 1).

Table 1. Summary of projects and publications.

Project Category	Number Projects	Project Semesters	Project Related Pubs	Offshoot Pubs
Web Applications	21	25	21	
Pervasive Systems	15	25	18	
PC Applications	11	18	13	
Artificial Intelligence	9	11	12	
Pattern Recognition	9	12	34	19
Biometric Systems	32	35	39	19
Quality Assurance	5	9	5	5
Totals	**102**	**135**	**142**	**43**

Table 2. Project sources.

Project Source	Number
Faculty Ideas or Research	42
Student Ideas or Research	36
External Community	13
Internal University Needs	11
Totals	**102**

Table 3. Publication categories.

Publication Type	Number
External Conference Papers	53
Journal Articles	7
Book Chapters	2
Doctoral Dissertations	17
Masters Theses	4
Internal Conference Papers	98
Internal Technical Reports	4
Totals	**185**

Example Projects and Websites

In a recent semester we had seven projects as shown on the Projects page of the course website (Figure 1). Most of the project customers that semester 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 (SME = Subject Matter Expert), a link to a detailed project description, and the student team (listing the team leader first). The project ID number is also a link to the student team website for the project. The team website for the "Keystroke Biometric" project is shown in Figure 2.

A continuing line of research, and one that brought forth many projects, is on the keystroke biometric, one of the less-studied behavioral biometrics. Keystroke biometric systems measure typing characteristics believed to be unique to an individual and difficult to duplicate. Over the last five years, long-text-input keystroke biometric systems for identification (one-of-n response) and for authentication (accept/reject response) have been developed. In this keystroke biometric area we have had about ten semesters of masters-level project work, four doctoral dissertations, three external conference papers, a book chapter, and a journal article.

Project Information

ID	Customer	Project	Student Team
1	Robb Zucker, DPS Dmitry Nikelshpur, DPS	Human Visual System Neural Network	Alexander Cipully Stamatios Cheirdaris Roberto Rodrignez Rohit Yalamanchi
2	John Stewart, DPS	Stylometry System	Edyta Zych Omar Canales Vinnie Monaco Thomas Murphy
3	Sadia Ismat, DPS Alex Alexandrou, DPS Dr. Narayan Murthy (SME)	Biometric Product Investigation	Juan Amadiz Jia Tian Liu Giovanni Lugones ShashankaTripuraneni
4	John Stewart, DPS Dr. Robert Zack (SME)	Keystroke Biometric: Data Collection & System Testing	Vinnie Monaco Tyrone Allman Mino Lamrabat Mandar Manohar
5	Ned Bakelman, DPS	Keylogger Keystroke Biometric System	Horace Henry John Delnca Pierre Folkes Dwight Worley
6	Brenda Lyons Jack Freeman Jenny Li, DPS (SME)	Social Network Business Site	Nancy Raffaele Yogita Ahire Jenifer Neubauer
7	Steve Kim, DPS	Social Network Forensic Tools	Andrew Kambad Vishal Almeida Palak Shah David Wilkins

Figure 1. Project information on course website, spring 2011.

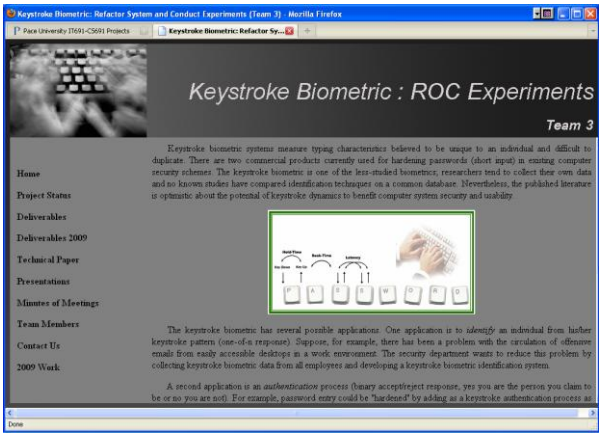

Figure 2. Example team website.

Teams, 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. It is widely accepted 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 email, 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.

4. PROJECT AND RESEARCH INTERPLAY

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 is to support student dissertation and faculty research 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.

We have found this interplay between research and project activities to be exciting and productive. 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 problems to provide projects, and using projects to supply computing infrastructure. We term this symbiotic relationship the research/project interplay.

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. 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. Masters students also have the option of a research thesis. 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.

5. COURSE MANAGEMENT

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 and Europe. 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.

The three 3-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 (half 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. 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.

Successful Teamwork at a Distance

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 Deliverables – lists and describes the project deliverables.
- 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, 2011) 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.

Blackboard Educational Software

The Blackboard educational software system (Blackboard, 2011) 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.

6. 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 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 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.

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 (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 4 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 4. Team peer evaluation and grade chart.

Team Member	Eval 1	Eval 2	Eval 3	Eval 4	Summary	Grade
1	+	=	+	++	+ + + +	93
2	=	=	–	– –	– – –	79
3	–	=	+	–	–	83
4	=	=	–	+	=	85
Average	**=**	**=**	**=**	**=**	**=**	**85**

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.

Customer Evaluations

At the end of the semester we survey the students using the Survey Monkey (2011) 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.

7. OVERALL BENEFITS

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.

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. Our 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. 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 customers include the research students, the faculty, the internal and greater university communities, and the community non-profit and technology organizations. The work with other universities, such as the Rensselaer Polytechnic Institute, extends our collaboration to the greater 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.

8. 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 exist. 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 archiving documents.

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