Mobile App Development: A Cross-Discipline Team-Based Approach to Student and Faculty Learning

Dr. Sarvesh S Kulkarni, Villanova University

Sarvesh Kulkarni received a B.E. in Computer Engineering from the University of Bombay in 1994, and the M.S. and Ph.D. degrees in Computer Science from the University of Texas at Dallas in 1998 and 2002, respectively. Prior to 2002, he has worked in various industry positions in India and the US. He joined the ECE department at Villanova University in 2002, and is currently an Associate Professor of Computer Engineering. His teaching and research interests are: adaptive load-balanced techniques for routing packets in wireless and wired networks, performance analysis and optimization of network parameters, rapid prototyping of autonomous robots, and networked health-monitoring device in healthcare applications. In 2011, he won an award from the Global Consortium of Entrepreneurship Centers for teaching innovations in a team-taught multi-disciplinary course.

Dr. Frank Klassner, Villanova University

Dr. Vijay Gehlot, Villanova University

VIJAY GEHLOT is an Associate Professor and Graduate Programs Director in the Computing Sciences Department at Villanova University. He received a Bachelor of Engineering (Hons.) in Electrical and Electronics from Birla Institute of Technology and Science (BITS), Pilani, India; a Master of Engineering in Automation from Indian Institute of Science (IISc), Bangalore, India; and a Ph.D. in Computer and Information Science from University of Pennsylvania (UPenn), Philadelphia, Pennsylvania. His research interests are in the area of systems modeling and analysis, formal methods, and applications of Colored Petri Nets (CPNs). He has used CPNs to model and analyze network protocols, service systems, biological pathways, healthcare systems, enterprise architectures, re-entrant systems, and broadband services. He is a member of the ACM and Sigma Xi. His email address is vijay.gehlot@villanova.edu

Mr. E.J. Dougherty III, Villanova University

E.J. Dougherty III is an Adjunct Professor in the College of Engineering at Villanova University, teaching courses in Engineering Entrepreneurship and Mobile Application Development. He received both his B.S. and M.S. in Computer Science from Villanova University. E.J. is also Vice President of a project-based technology company, Ablaze Development Corp, specializing in the design and development of working proof-of-concept software and hardware systems.

Ms. Sue McFarland Metzger, Villanova University

Sue McFarland Metzger received a B.S. in Mathematics from Bucknell University in 1987 and a M.S. in Engineering from the University of Pennsylvania in 1995. Prior to 1995, she was a programming and database management consultant and specialized in client/server deployments. From 1995 until 2003, she worked for SAP supporting global software implementations. She joined Villanova University in 2003 and is currently an Instructor of Information Systems in the Villanova School of Business. Her teaching and research interests are: enterprise systems, programming, mobile application development and entrepreneurship, database management and business analytics.

Dr. William P Wagner, Villanova University

Dr. Wagner is a professor of Information Systems at Villanova University where he has been teaching since 1991. He received his Ph.D. in MIS from the University of Kentucky in 1992. While at Villanova he has developed over 30 innovative new MIS courses. He has co-authored three books and many journal articles in the fields of CRM, Enterprise Systems, Expert Systems and E-Commerce. Recently, he was the winner of the 2011 Meyer award for Innovation, Creativity, and Entrepreneurship and a co-winner of the 2011 Global Consortium of Entrepreneurship Centers' award for Excellence in Entrepreneurship Teaching and Pedagogical Innovation.

Mobile App Development:
A Cross-Discipline Team-Based Approach to Student and Faculty Learning

Abstract

Technical courses taught in a university setting focus exclusively on technical elegance. Although such a narrow, academically rigorous approach is successful in imparting technical competence in the subject at hand, students do not get an adequate sense of how the practitioners in their profession interact with their counterparts in other professions in the real world. The aim of our cross-disciplinary "*Mobile App Development*" course is to remedy this missed opportunity by providing an opportunity for students and faculty members from three different disciplines (engineering, computer science, and business) to experience and learn the nuances of each others' fields, while simultaneously introducing the concept of entrepreneurship. Such an unorthodox mix of students sharing a single classroom calls for non-traditional teaching strategies and evaluation techniques. This paper discusses those techniques, the challenges involved in meeting the stated outcomes, and three iterations of refinements in the evolution of the course leading up to its current format. An interesting aspect of the course is that each cross-disciplinary student team is expected to deliver a "close-to-market" mobile application product by the end of the course that is jointly assessed by the course professors and external judges from industry. Lastly, although this course requires significant teaching effort, the instructors, the participating students and our University is convinced that the benefits of such collaborative learning are worthy of further investments.

I. Introduction

As early as 1916, J. Dewey propounded the complementary ideas of experiential learning and interdisciplinary learning.[1] H. Taba, a student of Dewey's, expanded the field of progressive learning by introducing inductive and creative learning techniques.[2] Students were encouraged to organize related concepts from two or more diverse fields of learning, into groups. Ackerman, Perkins and Jacobs[3] put forth very strong arguments in favor of a combination of discipline-specific as well as complementary inter-disciplinary learning. Furthermore, they emphasized the importance of interweaving skills and knowledge-based content in the learning process.

Today, many university programs try to integrate experiential and inter-disciplinary learning in their curricula. For instance, some courses attempt to introduce experiential leaning through inter-disciplinary projects.[4] Others teach loosely related topics using a unifying theme in fields such psychology[5] and biology.[6] However, most inter-disciplinary courses usually focus on the depth of specific content in a couple of disciplines rather than the breadth, i.e. integration of content across a variety of disciplines. More specifically, all students taking such an inter-disciplinary course are required to master the skills and the content equally well regardless of their core discipline. An immediate shortcoming of this approach is that it severely restricts the diversity of student participants with respect to their prior preparation. Thus, cross-pollination of ideas among students of diverse disciplines is not easily achieved. In the real world, it is more reasonable to expect that when working in a team, team members are experts in their specific fields, but are less familiar in other areas. Consequently, as a practical matter, project leaders

strive for diversity in a team's aggregate expertise rather than rely on a few superhuman members with diverse skill sets.

Even when inter-disciplinary courses are taught in technical programs such as engineering and computer science, the focus is usually on attaining a technically elegant solution. The economy and timeliness in reaching the said solution are usually ignored. The unfortunate side-effect is that many engineers and scientists believe that a great idea sells itself regardless of market dynamics. The lack of understanding of how a business functions may lead to adversarial relationships between technical employees and their business-oriented colleagues.[7, 8] Similarly, when business managers interact with their technical employees, they often do not fully appreciate the complex nature of the technical development process and the numerous missteps on the way to a successful product.

Therefore, in designing and refining a course for students with diverse academic backgrounds, we had the thematic goals of helping them: i. learn a variety of interconnected topics through experiential means while allowing them to contribute significantly in their area of expertise, ii. interact with other students with very different academic backgrounds in a classroom/laboratory setting and, iii. develop empathy towards, and a greater understanding of each others' professions by making them "walk in each others' shoes" in a cross-disciplinary team-taught course. In addition, student groups are encouraged to propose and select their own semester-long course projects that directly complement these thematic goals. Thus, in accordance with Dewey's main ideas[1], we not only attempt to emulate a real world cross-disciplinary experiential learning environment, but also democratize the project selection process in order to enhance the students' investment in their work. Furthermore, in accordance with the ideas put forth by Ackerman et al.[3], we interweave class instruction (knowledge-based content) with project work (skills) in order to facilitate learning.

This paper describes the initial design and the iterative refinement of our cross-disciplinary *Mobile App Development* course over a period of three years. The rest of the paper is organized as follows. Section II outlines the reasons for selecting *Mobile App Development* as the course's unifying theme. Section III discusses the practical constraints that we placed on our course in addition to the thematic goals listed above. Section IV describes the objectives, organization, syllabus and pedagogical approach that we designed for the initial course offering in Spring 2010, as well as the assessment of the course. Section V describes the refinements incorporated in the second offering of the course based on the assessment of the first offering, as well as its own assessment. Section VI describes the further refined, third offering of the course based on assessment of the second offering, and its own assessment. Section VII concludes the paper by discussing the salient points of the course and providing some assessment-based inferences.

II. Course Topic Selection

A *Mobile App Development* course is a good candidate for a cross-disciplinary effort since it involves a combination of both technical and nontechnical topics. For instance, in order to successfully develop an application (app), one needs to learn at least three or four of the following: mobile application programming on one of two different platforms (Android and

iOS), complementary data structures, user interface design, networking and communication, the use of on-board sensors, and security. In order to successfully sell such an app, one needs to be entrepreneurial in analyzing the market need and its potential size, then construct a business plan, explore avenues for developmental funding and revenues, and design a marketing strategy. In addition, one also needs to hone one's soft skills such as presentation of ideas to appeal to a group of investors and the complementary one-minute "elevator pitch."

Furthermore, from an entrepreneurial perspective, mobile app products have a low barrier to entry in the marketplace. The initial platform investment consists of a smartphone, which most students already possess, and a software development kit with a developer's license (free for Android, under $100 per year for iOS). Once the app is ready, the vendor running the app-store provides free hosting services and payment. This eliminates any up-front cost and time overhead incurred by the developer to set up a storefront and a payment processing system. Therefore, such a system is ideal for small development teams with a low startup budget.

Clearly, a course using mobile apps as the unifying theme weaves many individual, diverse subtopics together and presents a very good opportunity for students to experience the intricacies of each other's disciplines; it allows them to work closely with students of a different mindset and gain a better understanding of viewpoints other than their own. Such a course naturally lends itself to team-teaching and requires a combination of traditional and unconventional student and course evaluation techniques that mirror both the academic as well as the real world. As a practical matter, the course is housed in the Department of Computing Sciences, but brings together faculty and students from disciplines in three colleges: College of Engineering (Electrical and Computer Engineering majors), College of Liberal Arts and Sciences (Computer Science majors), and Business School (various business majors). The following section describes the features that were maintained across all offerings of our *Mobile App Development* course.

III. Overarching Course Design Features

An entrepreneurial theme was considered essential to the *Mobile App Development* course; there were guest lectures by entrepreneurs and industry practitioners on topics such as business plans, creative thinking, project management techniques, and technical trends in the app industry. Students were also challenged to understand that no matter how technically "showy" their app ideas are, they must be adapted to market trends and user acceptability testing. In addition, students need to realize that this requirement must be met even if they are developing apps for a large corporation's captive in-house audience; managers will not want to invest person-months on projects that will not be used because the design did not take the corporate culture into account!

We also decided that the course would benefit from a semester-long project that is proposed and implemented by multi-disciplinary teams of students. The teams are responsible for justifying their interface design, marketing strategy, and implementation based on technical considerations as well as on business and entrepreneurial research. By the end of the course, students are expected to deliver a "close-to-market" mobile application product along with a business plan for the monetization of their product. In the project, each participant observes and experiences the nuances of the others' fields: in developing their product, business students sometimes program,

but always exert influence on the app design from a usability and marketability perspective, while engineering and computer science students help develop business and marketing plans with advice on what is technically feasible. Computer engineering and computer science students learn about the harsh realities of business decisions, and business majors learn the technological challenges, limitations, and thought processes that go into designing a technical product.

It was further decided to make the course approximate a platform-neutral environment by initially supporting both iOS and Android. Later, HTML5 support was added. This decision was made based on several observations. First, we foresaw that the overhead of trying to purchase enough of each year's latest smartphone and tablet models for a class of thirty students would overwhelm our financial resources. Therefore, it was decided that students would use their own devices for development, which again would lead to biases in their platform choices unless we took a concerted platform-neutral approach. The course attracted enough attention for Verizon Wireless to contribute five free mobile phones with unlimited data plans for those students that did not own smartphones. Second, given the multi-platform nature of the mobile app field, we felt that it was important for students to experience one long-term project with one platform. In addition, some familiarity with other platforms was also needed so as to objectively evaluate platform suitability for future projects. Third, students from each college come with different programming backgrounds: some have primary programming experience in *C*++, while others are proficient in Java, Visual Basic, or Javascript.

The instructors are rotated year to year within each contributing department to allow the department chairs some flexibility in their teaching schedules. Each instructor is experienced in at least one of the development platforms. The maximum enrollment is thirty students with the constraint that no more than ten students may be drawn from any one discipline during initial registration. After the initial three-week registration period, this constraint is lifted. This practice ensures that students from all three disciplines get a fair share of the available seats. It also supports the creation of diverse development teams with one student from each college per team.

In order to support the course goal of fostering entrepreneurial thinking, instructors discussed the nature of entrepreneurship with students using definitions such as "working to meet people's needs before people realize they have the need," and Stevenson's classic, "the pursuit of opportunity without regard to resources currently controlled." [9] After discussing several case studies, students were then invited to identify opportunities within the mobile app arena: what needs do they think that they, their peers, or their families have, that could be addressed with apps; how could existing apps be improved to better meet consumers' needs? In the first two course offerings, students discussed their ideas and formed their own teams within the group membership policy presented earlier in this section. In the third and fourth course offerings, we formalized the team creation process by encouraging students to post their reflections on an "Idea Bounce" blog; the students then "pitched" their app ideas in class, and listed their three best ideas in order of preference. The instructors then matched students to create teams based on these preference lists.

In addition, instructors provided general advice about categories of resources a team might need for its project. However, in keeping with the Stevenson's entrepreneurship definition, each team was expected to identify and seek out the specific resources they would need for building their

app (e.g., programming skills, developer licenses and tools, artwork, database servers, etc.). In recent course offerings, student teams are also required to make engaging formal pitches (e.g., video promotions, acting, video editing, elevator pitches, and app demonstrations) at the Student Entrepreneurship Competition (SEC) for a panel of business leaders, venture capitalists, and entrepreneurs drawn from across the country.

IV. First Course Offering

This section describes the design of our course and highlights its entrepreneurship-focused project-centric, cross-disciplinary learning approach. The course description here will also be the basis for describing what changes were made in later offerings and why they were made. Therefore, sections V and VI will only highlight the modifications from the first course offering.

A. Course Design

The Spring 2011 *Mobile App Development* course was announced with the following goals:
- foster entrepreneurial thinking
- create an awareness that a real-life approach to product development spans multiple disciplines, and
- demonstrate the value of collaborating with peers across disciplines to champion one's vision; success is not guaranteed, but it is not incidental either

There were two weekly 75-minute class sessions. In each week, one session was dedicated to classroom instruction, and the majority of the other session was dedicated to student team development, with faculty available for consultation on the teams' programming questions. Instructors took turns teaching discipline-specific topics in modular styles. All instructors attended every class along with the students and participated in class discussions, regardless of which instructor was scheduled to present a lecture. The intent was to convey the message to the students that topics outside their fields are just as important as those within their fields for success in the course. There were three guest lectures from entrepreneurs in the local Philadelphia mobile app startup community. Students were expected to write summaries of these presentations and critique them for style and content in the following class session.

The main topics for lecture presentations and their presentation order were:
- Programming apps in Android or iOS platforms and platform emulators
- Comparison of the iOS and the Android ecosystems
- Design and implementation of a clean and coherent user interface (UI).
- Market analysis and entrepreneurial opportunities
- Business plans, product marketing and monetization
- Device communication using Bluetooth and TCP/IP protocols
- Accessing and using data from smartphone sensors
- Intellectual Property: rights, agreements, and responsibilities
- Comparison of Web apps and HTML5 apps with native apps
- Effective techniques in pitching products to potential investors, and full rehearsals.

In addition, supplemental lectures on security were added later upon student request. No required course text was specified.

The second session each week was designated for work on team projects. In the initial few weeks of the semester, the emphasis in these sessions was on organizing the app ideas and creating rough implementations of the app interfaces using standard layout schemes as much as possible in Android and iOS. Later, teams used this time period for writing "Project Milestone" assignment reports, developing business plans, and integrating code from extracurricular team meetings and code libraries available on the internet.

A core component of the course was a semester-long group project that included a complete life-cycle of app development from idea, to business plan, to coding and market feasibility. Central to the project was the cross-disciplinary, experiential learning component; therefore, the execution of the team project required the students to perform the following steps in a timely fashion. Students were required to form teams comprised of three members, each from a different major. They then selected either the Android or the iOS platform for their projects, and proposed an app idea along with a set of features for implementation. The proposals were evaluated by the instructors for technical and economic feasibility. Based on the feedback they received, they either revised the scope and focus of the project, or proposed an alternative one.

Students were graded as follows: 30% Project, 20% Final, 20% Midterm, 20% Project Milestone Assignments, and 10% Class Participation. Thus, 50% of their grade depended on the project. Students were advised regarding their app projects in that their app grade would depend on how complete their apps were based on their second-draft proposals; if promised features were missing, significantly lower grades would be awarded. Students were allowed to form their own teams. They were discouraged from choosing games as their app idea since games apps tend to require extensive graphics skills and design time; the instructors felt that one semester was too short a time-frame for students with heterogeneous programming experience levels to complete a plausibly compelling game app.

Examinations were designed to be uniform for the course population, which meant that students were responsible for understanding material from outside their major. The examination questions were vetted by all three instructors to ensure they were not over-dependent on any narrow discipline-specific material covered outside of the *Mobile App Development* course.

Once the project selections were finalized, the students undertook a broader market study to determine the implementation features in their app deemed to be absolutely essential. Other features were prioritized based on the competitive advantage that they would provide the app vis-a-vis other market competitors. Next, students designed the screen art, the user interface (UI) screens, and created mock-ups using free-hand sketches or computer-based tools. The instructors then evaluated the UI designs for aesthetics as well as usability i.e., color visibility of and contrast between UI elements, placement of buttons, the readability of labels, coherence of themes, logical grouping of app controls, etc. Student teams were expected to take this feedback into account in refining their UI.

The development of a business plan proceeded in parallel with the app development activity. The student teams had to identify and study the potential market for their app, determine market positioning of the app, perform a strength-weakness-opportunities-threat (SWOT) analysis, identify and project revenue streams, costs, required financing, and the breakeven point. Thus, the intricate interweaving of business and technical topics during the execution of the project provided an opportunity for very close interaction among all team members.

At the end of the semester, all team members had to provide a demonstration of their working app along with the business plan to the entire class, faculty, and selected external reviewers. Each project was evaluated by faculty and external reviewers on metrics such as the degree of completion, aesthetic appeal of the UI, the workability of the business plan, and the quality and appeal of the presentation to potential investors.

B. Assessment

We used a variety of formal and informal assessment techniques in order to examine whether our course goals are being met. We then used the results of the assessment to refine the course content and focus on subsequent offerings.

For year one, we relied on the University-administered generic year-end Course and Teacher Survey (CATS) for instruction related data about the course. However, these questions did not address any course-specific goals. For subsequent offerings we created a separate anonymous course-specific survey for students. A sample of these questions is given in **Table 1**, Section V.B. In addition, in year two and three, internal and external judges assessed entrepreneurship-related outcomes using a separate set of criteria (see **Table 2**, Section V.B).

Although course specific survey data was not available in year one, we did use the written comments on the CATS to assess the problem areas and revise the second offering. In these comments, the students felt strongly that their programming capabilities in any given platform varied tremendously.

V. Second Course Offering

A. Course Refinements

In order to reduce the disparity associated with programming skills, we decided to include mandatory programming exercises for all students based on AppInventor, which is an Android-based, easy to use, automated platform for building mobile applications (an equivalent aid was unavailable for iOS). The objective was to provide some practice to all students to implement a small app in preparation for their course project. Later, however, students were free to choose (and they did choose) any platform for their course project.

The introduction of AppInventor allowed us to increase the frequency of deliverables, enforce stricter milestones and identify unmotivated students. However it required a disproportionate amount of instructional resources for platform maintenance, and diverted attention from the key

focus of the course. We found that students still chose platforms emotionally, not rationally; their comments indicated that they still saw themselves in traditional roles in alignment with their majors. However, the silos did break down somewhat and AppInventor did help business students (only business students agreed with the question *"it was useful to explore the mobile platform via AppInventor projects"* on the course survey). Planning averted lost class sessions due to last-minute guest speaker cancellations as we had prepared extra material for presentation.

In order to provide the students a real world experience, we linked project presentations with a University-wide entrepreneurial competition called the *pitch day*. Student teams (groups) were required to "pitch" their ideas and working demonstrations to external judges from a pool of entrepreneurs, business leaders, industry practitioners, and even venture capitalists. All student groups had working demonstrations for the *pitch day*, which exceeded even our expectations. Critiques and comments collected from external judges indicated that they were rather impressed with the groups' achievements.

B. Assessment

In year two, in addition to CATS surveys, we created a separate anonymous survey containing questions specific to course goals and design. A sample of these questions is shown in **Table 1**. For each question, a range of responses from *Strongly Agree* to *Strongly Disagree* were collected and analyzed. These questions were designed to address course-specific goals including the team-based multi-disciplinary approach as well as platform neutrality.

Table 1: Sample questions from anonymous survey used in year two and three

Question ID 12	The course met the goal for me to learn about the business of mobile app development.
Question ID 14	The course met the goal for me to learn how to program a mobile app.
Question ID 15	It was important to me to have the option of working with the Android or iOS platforms.
Question ID 19	It was valuable to hear what entrepreneurs are doing in the area of mobile apps.
Question ID 22	The course met the goal for me to learn about how to write a business plan.
Question ID 26	The course met the goal for me to learn how to design user interfaces for mobile apps.
Question ID 30	The course met the goal for me to learn about the strategy and marketing behind mobile app development.
Question ID 31	It was valuable to me to work with team members from other colleges.

The summary of results for selected questions in **Table 1** is given in **Figure 1** below. In compiling this data, for the purpose of current discussion, we have collapsed *Strongly Agree*, *Agree*, etc. into one category called *Agree*. Similarly, *Strongly Disagree, Disagree*, etc. have been merged into just *Disagree*.

Question IDs (QIDs) 12, 19, 22, and 30 were designed to address the business and entrepreneurship aspects of mobile app development. The response to QID 22 indicated that the course failed to adequately address the details of writing a business plan. It was imperative to correct this shortcoming in year three. Responses to QID 30 identified similar concerns in the study of strategy and marketing behind mobile application development. Responses to QID 31 indicate that we were successful in making the course team-based and multi-disciplinary. The
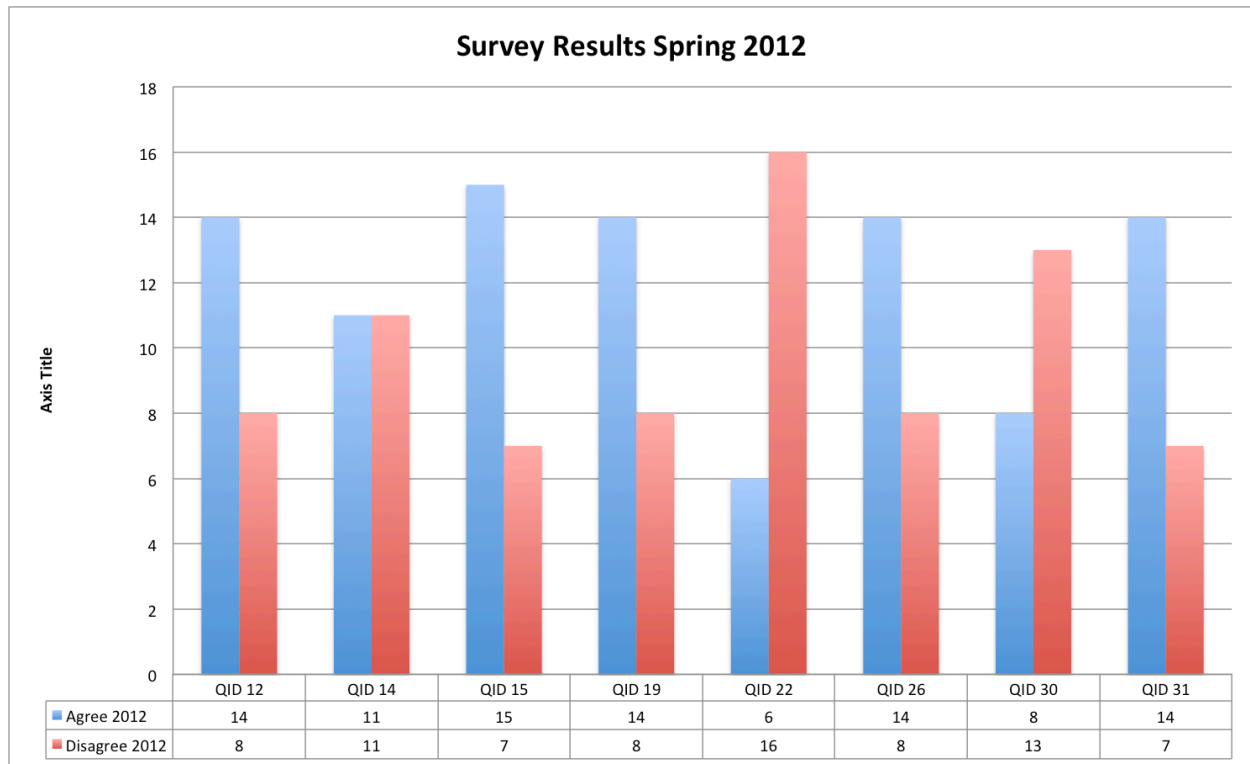
Figure 1: Course Goals Survey Results Spring 2012

introduction of AppInventor did help augment the programming capabilities of business students, but the class as a whole was divided in terms of their learning goals in this regard (QID 14).

The *pitch day* (described in Section V.A) at the University provided a synergistic avenue for our students to "pitch" their apps and gain impartial feedback from both internal and external judges. Evaluation criteria were provided to all judges. The three selected evaluation criteria that specifically evaluated entrepreneurship-related learning outcomes are listed in **Table 2** and were based on the concepts outlined by Stevenson.[9]

Table 2: Sample Pitch-Day Evaluation Criteria for Entrepreneurship

Prototype Evaluation	How mature is the concept? Is the key functionality complete; has it been demonstrated? Is the product tested and usable?
Business Plan Evaluation	Are market assumptions reasonable and correct? How do you rate competitive analysis, feasibility, market strategy, and appeal of the product?
Business Value Evaluation	Does this idea/execution have potential? Would you invest? Is there anything that stood out?

Figure 2 shows the minimum, maximum, and average scores awarded to each group by the judges on a 10-point scale (10 being the highest) to the pitched apps according to the criteria listed above. G1 through G5 on the *x*-axis refer to student groups.
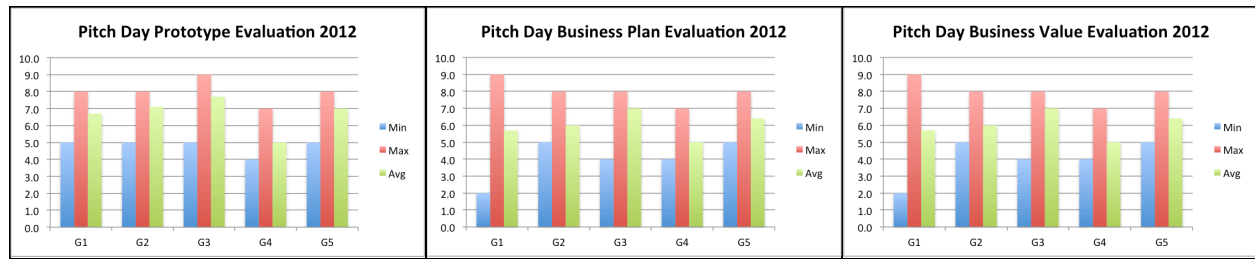
Figure 2: Pitch-Day Evaluation of Entrepreneurship Skills Spring 2012

The graphs in the figure indicate that most groups achieved better than average scores on all three evaluation criteria. If we ignore the poorest performing group (G4), it is apparent that while the technical prototypes are rather well received, the average scores on business plans and value evaluations are just above average and need improvement. Therefore, the students seem to have focused most of their attention on getting the app functional, but did not spend as much effort on the business aspects of their work.

VI. Third Course Offering

A. Course Refinements

One evolution has been the addition of a two-week, three-way mini-project in the third offering that sets up three-member student teams and introduces all students on a team to all platforms through demonstrations and discussions of their experiences implementing the same mini-project three ways (one student per platform). It runs concurrently with the early part of the course when students are in the process of selecting their semester-long project and development platform. We plan to expand this mini-project to a three-week project in the fourth offering of the course. Furthermore, on account of the weak business focus as evidenced in the pitch day evaluations of group projects, the instructors stressed the importance of this aspect and made additional business and marketing material available to students. Each student group was afforded an opportunity to rehearse its pitch in front of its peer groups and faculty, and was provided constructive feedback.

Since each student group could work on a different project of its own choosing, some teams realized that they needed to learn additional subject matter that was not taught in class. For instance, the use of a gyroscope in conjunction with an accelerometer for detection of linear and angular motion requires the fusion of data from these sensors, a considerably complex topic. It requires an understanding of how these sensors work, their limitations and the physics involved. Such a topic is well outside the scope of the class; however, in such instances, the instructors created notes and examples and posted them online for self-study for interested students. Over time, and over multiple offerings of the course, the knowledge base grew more comprehensive.

B. Assessment

As in year two, we collected data from a course specific survey in year three. The summary of results for selected questions in **Table 1** is given in **Figure 3**.
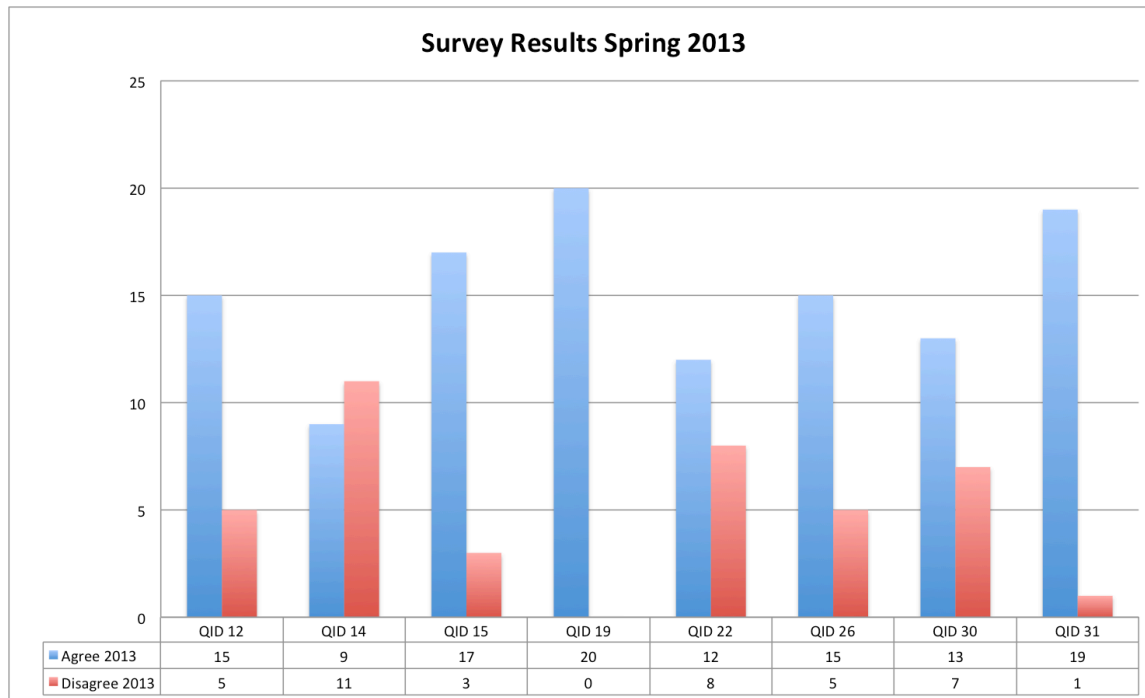
Figure 3: Course Goals Survey Results Spring 2013

Here we see an even stronger evidence of students recognizing the value of a team-based and multi-disciplinary approach to learning (QID 31) and entrepreneurship (QID 19). Again, we see that the class opinion is divided on the development of their mobile programming skills (QID 14). Our analysis of the responses to QID 14 is that when answering this question, students are assessing their own individual capability and not necessarily the capability of the team as a whole. We intend to rephrase this question in the future to clarify the matter.

The entrepreneurship-related learning outcomes were assessed again in 2013 on *pitch day*. Judges used a 5-point scale (5 being the highest) to evaluate each student group as per the three criteria identified in **Table 2**. **Figure 4** shows the resulting minimum, maximum, and average scores awarded to each of the groups G1 – G5. The scores have been converted to a 10-point scale for uniformity with **Figure 2**.
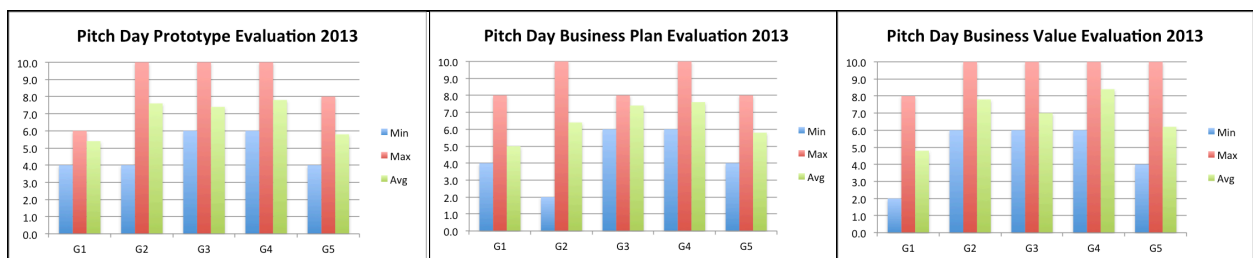

Figure 4: Pitch-Day Evaluation of Entrepreneurship Skills Spring 2013

The graphs in the figure indicate that, again, most groups achieved better than average scores on all three evaluation criteria. If we ignore the poorest performing group (G1), it is apparent that

while the technical prototypes were still well received, the average scores for business plans and business value evaluations show a definite improvement from the prior year.
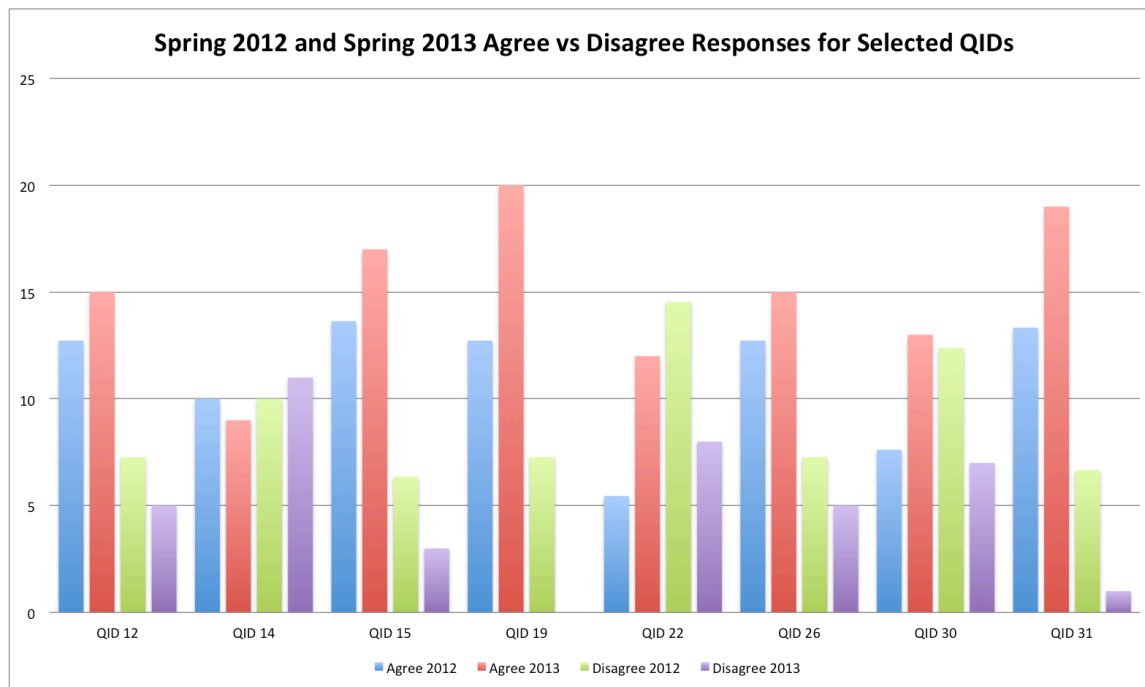

Figure 5: Survey results comparison for 2012 and 2013

VII. Conclusion

The *Mobile App Development* course was developed in order to encourage cross-disciplinary, collaborative learning among students with diverse academic skills using a strong entrepreneurial framework. Students and faculty from three different colleges interact closely and synergistically in a project-driven course. The expectation is that through interaction with one another, students will be better able to appreciate the finer points of each others' disciplines. While the journey so far has been challenging, continuous refinements to the course have made the goals quite attainable.

Our partnership among three colleges/majors is one of the course's main distinguishing features. Another distinguishing feature is the platform-agnosticism, with iOS, Android and HTML5 being supported in equal measures; most courses in other Universities that we know of adopt one or the other. This is also the source of our biggest pedagogical challenge as we strive to keep students from different platforms engaged when their platform is not being discussed.

Formal assessment by means of student surveys in **Figures 1** and **3** indicate that students value both the academic contributions and the entrepreneurial aspects of the course. **Figure 5** demonstrates that the third offering of the course (in 2013) met its objectives better than the second offering (in 2012). Further, entrepreneurship-related outcomes were assessed using three specific evaluation criteria. In particular, using these evaluation criteria, feedback on the quality and business-readiness of student apps was provided by internal and external judges on *pitch* day

at the University-wide entrepreneurial competition. **Figures 2** and **4** indicate that the technical maturity of the apps was clearly evident according to the judges in both the 2012 and 2013 offerings of the course. In addition, while the business maturity of the apps was somewhat lacking in 2012, targeted efforts during the course refinement process yielded better results in this area in 2013. The contribution of the entrepreneurial component was further evident when a cross-disciplinary student team from this class won a University-wide award in 2013 (out of forty participating teams) in an entrepreneurship competition for an app developed as part of the class deliverable. Furthermore, entrepreneurial activities are encouraged and supported by an innovation center in the business school even after the course concludes.

An informal measure of a course's success is its popularity and wide appeal. The *Mobile App Development* course has run successfully for three consecutive years with enrollment at 80% to 100% of scheduled capacity (30 students) and the fourth offering is now running at full capacity as well. Furthermore, the innovations introduced in the course won three of the instructors an award in entrepreneurship teaching and pedagogical innovation from the Global Consortium of Entrepreneurship Centers, a consortium of more than 200 University centers.

Lastly, we would like to note that although we collected data both formally and informally on student learning, we did not have an explicit mechanism in place to collect data for faculty learning. Nevertheless, the lessons learned in the planning, design and refinement of this course and the complex logistics behind it were invaluable and were widely disseminated to the wider faculty within the University. While such a cross-disciplinary, entrepreneurship-focused course can prove to be rewarding to students and faculty alike, it does need significant administrative and material support from the university in order to make it successful.

Bibliography

1. J. Dewey*, Democracy and Education: An Introduction to the Philosophy of Education*, Macmillan, 1916.

2. H. Taba, M. Durkin, J. Fraenkel and A. McNaughton, *Teachers' Handbook to Elementary Social Studies: An Inductive Approach,* 2nd edition, Addison-Wesley, Reading, MA, 1971.

3. D. Ackerman and D. N. Perkins. "Integrating Thinking And Learning Skills Across The Curriculum.", *Interdisciplinary Curriculum: Design and Implementation*, H. Jacobs, Ed., Association for Curriculum Supervision and Design, 1989.

4. R. Caverly, H. Fulmer, S. Santhanam, P. Singh, J. O'Brien, G. Jones, E. Char, F. Mercede, R. Weinstein and J. Yost, "Project-based Freshman Engineering Experience: The Core Course," *ASEE 2010 Annual Conference and Expo,*, June, 2010.

5. R. J. Sternberg and J. Pardo, "Intelligence as a unifying theme for teaching cognitive psychology," *Teaching of Psychology*, Vol. 25, No. 4, pp. 293—296, Nov. 1998.

6. S. Offner, "Teaching biology around themes: Teach proteins & DNA together," *The American Biology Teacher*, Vol. 54, No. 2, pp. 93-101, Feb. 1992.

7. J. D. Weinrauch and R. Anderson, "Conflict between Engineering and Marketing Unit," *Industrial Marketing Management*, 11, 293-301, 1982.

8. V. L. Crittenden, L. R. Gardiner and A. Stam, "Redeeming Conflict Between Marketing and Manufacturing", *Industrial Marketing Management*, 22, 299-309, 1993.

9. H. Stevenson, "A Perspective on Entrepreneurship," Harvard Business School Working Paper #9-384-131.