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Smart Phone App Development: A Multi-College Approach

I. Abstract:
Smart Phone App development is exciting and timely, with potential for jobs, business incubation and revenue. Successful industrial App teams bring together professionals in arts, engineering, business, etc., to create elegant and user-friendly engineering marvels. Over the past three years, we have worked towards creating a microcosm of this at our university at the undergraduate level. State-of-the-art courses on this topic have been offered in three colleges, synergistically and concurrently, with the aim to team up faculty members and students from various colleges to work together towards this ideal. We have refined the process to a fairly repeatable and robust process over the past three years. We will present the lessons we have learned from our teaching and research that has led to this. We will provide sufficient information so other professors can replicate our work.

II. Background:
Apple[1] and Google[2] have championed the seamless integration of functionality (an engineering focus) with aesthetics, user-friendliness, relevance and empathy. It was our objective to develop project oriented courses that integrated these aspects at the university level.

Our long journey towards this was inspired by ABET's[3] accreditation criteria 3(a-k) that map well to team-oriented semester long projects, as envisioned and implemented in the capstone projects of an engineering curriculum. However, not all the criteria can be met in the capstone projects. The capstone projects also tend to vary much in quality and focus, leading to demands on faculty and student members alike. This led us to utilize the lessons learned from a six- year long industry funded project on significantly increasing engineering design productivity[4]. The referenced paper documents the mapping of the concepts and processes from an engineering design perspective to our academic project oriented three-course sequence. Further, once the engineering aspects had been addressed, we (at first, just the first author; later, the first and second authors, etc.,) had to start conversations with similarly inclined faculty members in other colleges. We were able to achieve this by inviting them first to be judges, then mentors, and then eventually teachers in joint courses. Once we had a core group of faculty members motivated to collaborate, we jointly signed up for certification from our university for teaching eLearning courses. This has allowed us to teach courses online and thus ultimately reach all potential students who can now form and operate teams across our multiple campus sites and in the cyber world. This will also allow us to potentially train professors elsewhere to replicate our efforts at their institutions, to teach joint courses that are face-to-face (F2F), online, or a blend of both.

Bringing together engineering, arts and business majors would be a major challenge in academia, since typically successful academic collaborations span only two colleges. However, we had to work towards that ideal since these three areas represent the core of any successful App. We believe we have achieved this. There, however, are two other core areas that are also equally important: content providers and ethnographers. The former are needed to ensure that the App developed is relevant to the domain being addressed. Inclusion of content providers is next on our list. The inclusion of ethnographers was neither obvious nor planned for. It was a happy accident when the third author from anthropology got involved as a content provider. He and his students quickly realized that they are more effective as ethnographers, rather than as content providers for social and medical Apps. We now realize that with their help these interdisciplinary teams of business, engineering and arts majors can function as a team and resolve their 'cultural' and professional differences on a timely basis. So, we now strongly believe that every App team to function in a predictable and goal-oriented manner must have members from business, arts, sociology/anthropology, and engineering (BASE) in the team. We will detail their roles below.

We have offered such a joint course as a face-to-face (F2F) course at both undergraduate and high school level several times over the past four years. We have also offered engineering graduate courses that had both engineering and arts graduate students enrolled. However, we need to make two remarks to clarify these general statements: (1) this paper will only focus on the undergraduate student level collaboration (see Fig. 1), and (2) the joint courses have involved anywhere from two to four disciplines, with more current ones being four-way. Reason for the second item is obvious: Our collaboration has progressed in an incremental fashion over the past four years. It was organic and was not planned for by the college administrators in a proactive manner. However, we made presentations to these administrators and invited them to be judges and guests of honor, to ensure that we communicated our goals well and secured their support. With future successes in App marketing it will be easy to involve content providers as the fifth partner. We have also offered it as an eLearning course, where it was a two-way collaboration; however, the next offering will be a four-way collaboration. All these courses have been jointly taught by a group of professors from different colleges. We provide sufficient details below for others to reproduce our efforts at their institutions.

III. Overview:

III. A The Big Picture (See Fig. 2): We now have a three course sequence in place that advantageously will synchronize the skill set and App goals at three different academic levels. Graduate students in engineering and arts will create components/platforms in the Fall; Upper level undergraduate students from BASE (business, arts, anthropology/sociology, and engineering) majors will incorporate these and prototype Apps in the Spring; and high school students will create fun and game Apps from these prototypes [5,6] in a three-week Summer course, which may be easily and quickly marketable. The learning curve for the technology is too steep, and mix of skills is too demanding, to achieve it all in one single three credit course. This becomes clearer when described in the context of the taxonomy for educational objectives prepared by Anderson et al.[7]. They use a 2 dimensional noun-verb matrix to identify the level of a given objective, in terms of the required knowledge (A. Factual; B. Conceptual; C. Procedural; and D. Meta-Cognitive) and cognitive process (1. Remember; 2. Understand; 3. Apply; 4. Analyze; 5. Evaluate; and 6. Create). The higher alphanumeric value represents a higher level of complexity[7]. The mapping for our course is as follows: High School course to levels (A and B, 6); Undergraduate course to levels (B and C, 5 and 6); and Graduate course to levels (C and D, 3). A business team to be successful, our ultimate goal to show economic impact of our collaboration, will require expertise at levels (D, 5 and 6), reached with a mix of graduate and undergraduate students who have taken our courses. The high school pairing may seem paradoxical, but is appropriate here[8].

III. B The Multi-College Course: This undergraduate course involves one faculty member from each of the four disciplines in teaching their students. These students will complete their discipline relevant material by mid-semester. During the semester they will undertake a team project and work across disciplines in implementing a marketable App. The student teams propose their Apps to a group of industry professionals by the mid part of the semester. The professionals help the teams clarify their thinking and come up with a marketable App. The teams then focus on this App and develop the App within about six weeks before the semester ends. They make presentations to these professionals at semester end, who also grade their team work. The final grade is dependent on both their individual/sub-team performance in their individual disciplines (as determined by summative evaluations during the first-half of the semester) and their team performance during the second half of the semester (as per a team performance rubric recommended by the industry professionals[9]).

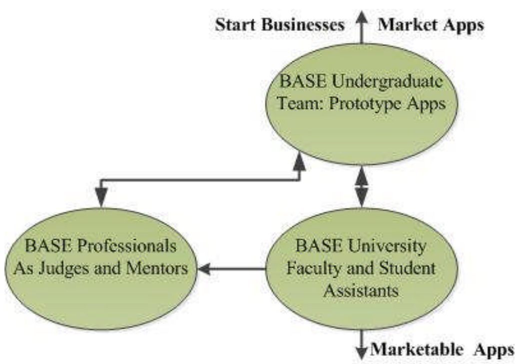

Figure 1: The joint undergraduate BASE course

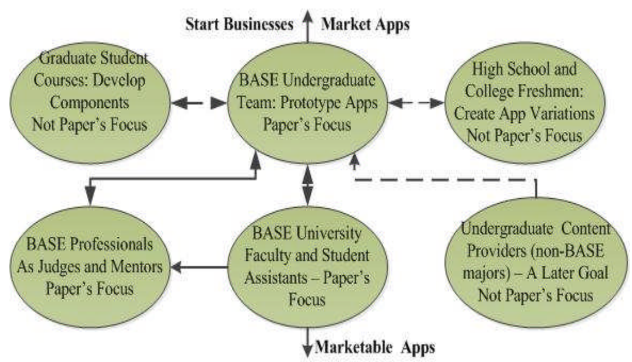

Figure 2: Our overall course flow and the connections to the BASE flow

III. C. Timeline: Table 1 below provides the timeline of our joint teaching over the past four years. This is provided only as evidence of the incremental refinement and exploration any process goes through. Though the figures above present today's well-formed pedagogy, the table tells a more nuanced story of continuous improvement and academic realities. Our focus in this paper is on the joint undergraduate (BASE) course.

Table 1: Course Details on an Academic Year Basis

Academic Year	Graduate Course (G)	Under-graduate Course (UG)	High School Course (HS)	Faculty Involved (G, UG, HS)	# of Teams and Typical Sizes (G, UG, HS)	Potential Apps (G, UG, HS)	Student Businesses Started (Known)
2009-10	No	Twice, E (56)	Once, BAE (29)	0, E, AE	(0,0), (16,3), (9,3)	0, 0, 5	2 (Active)
2010-11	Twice, E (48)	Twice, E (56)	Once, BAE (29)	E, ASE, AE	(20,2), (19,3), (9,3)	0, 5, 5	2 (Not Active)
2011-12	Once, AE (24)	Thrice, AE(39), BASE (62), AE (29)	Once, BAE (24)	E, (AE, BASE, AE), AE	(24,1), (20 with 3, 9 with 7), (8,3)	1,10,5	1 (Active)

Note: The first author was on sabbatical leave during the 2012-13 academic year.

III. D Course Sequence Details: This may be useful to other professors wishing to replicate our efforts while avoiding our stumbles.

- *Pre-Launch* (Fall 2008 - Summer 2009): We leveraged productivity lessons from a 6 year, $1M+ industry grant, to develop a three course sequence based on student capabilities at three levels (graduate, undergraduate, and high school). The Small Business Administration (SBA) provided us with a $123K grant to facilitate this [10].
- *First Year of Offering* (Fall 2009-Summer 2010): The Apps from the engineering undergraduate student courses became the prototypes or platforms that high school students used later that summer. Two engineering and two arts professors jointly taught the high school students [5, 6]. The high school students formed teams of three, with one student each responsible for engineering (programming), graphics (asset creation), or business (project management and promotional video creation) aspects. Nine engineering and graphics industry and academic professionals evaluated the high school student team projects. Five of the 9 game Apps (fun games) developed were deemed marketable by the judges. One engineering student started his own company and is successful today[11].
- *Second Year of Offering* (Fall 2010- Summer 2011): The graduate engineering course was offered. Students in such graduate courses developed a library of software components (on imaging, robotics, web services, etc.). But the hand-off to lower level students did not occur for technical reasons. In Spring 2011, a professor from Anthropology joined the team as a content provider, so the undergraduate engineering students could focus on developing social game Apps. These students were taught by the engineering professor and mentored by the arts and anthropology professors. One undergraduate student team won the second prize in our university's business competition[12]. That business is viable today. The summer 2011 high school course offered involved joint teaching by the engineering and graphics professors. Seven engineering, graphics and business professionals evaluated the work of 9 student teams. Five of the 9 game Apps (fun games) developed were deemed marketable by the judges.
- *Third Year of Offering* (Fall 2011 - Summer 2012): During Fall 2011, undergraduate students in engineering and arts took two concurrent courses taught by the engineering and arts professors. The two professors covered material relevant to their disciplines. Three to five engineering and arts students formed teams and focused on animation Apps. During Spring 2012, the teaching and student teams expanded to include all the four BASE majors. A total of 62 students from the four disciplines were concurrently taught by four professors, one each from these four disciplines. They were tasked to develop Medical Apps. Each team typically comprised of 3 engineering students, 3 business students, 1 arts students, and 0.5 anthropology student. The anthropology students participated as social observers (or ethnographers). The business majors were also content providers. Anthropology majors generated specific recommendations to improve team dynamics at both student and faculty levels. Judging was by a group of 8 BASE professionals [13]. One team was able to leverage their App, raise venture capital, and launch their company[14]. During Spring 2012, the first three co-authors also underwent eLearning designer/facilitator certification, an intense semester long course. A joint eLearning course was designed with the guidance of instructional designers[15]. Informal ethnographic research results from Spring 2012 were incorporated.

- *Details on Summer 2012:* Courses were offered at all the three levels. The graduate course focused on software automation so components can be generated in a more robust and comprehensive manner. This was taught by the engineering professor, but included both engineering and arts students. One student used the tools to develop an ABET accreditation software tool[16]. A joint undergraduate course was offered during Summer '12 to arts and engineering undergraduate students as an online course. Professors in engineering and arts taught their courses concurrently. Nine teams of 3 to 4 students completed Apps and were evaluated by industry professionals. A 3-week summer course for high school students was also offered. We tried a variation of our earlier course. We used App Inventor[17] for rapid prototyping. These high school students compared the use of App Inventor and Java (with Android SDK) for App development in terms of certain performance metrics (memory foot print, response time and power dissipation). The former has limitations (high memory need and App fragmentation), but is useful for rapid prototyping. Java, on the other hand, takes longer to develop an App with, but the result is a more sophisticated App.

III.E Typical Course Flow: We present here details of a composite joint course as we expect to conduct it in the future. It is based on multiple variations and combinations attempted over the past four years. The syllabi of the four concurrent courses are documented at a team site[15].

This is a joint teaching project that involves four faculty members from each of the BASE disciplines. Each of the BASE professors will teach one course that is discipline specific. Each of us will teach relevant material pertaining to our respective disciplines, then bring students together (after a mid-term summative exam to ensure that the students could contribute productively) to form cross-disciplinary teams to build mobile applications. All the courses have three specified 'lab' hours, with students signing up for two. This facilitates their interaction. The courses are on software and system development for smart phones (for engineers), animation and graphics for mobile applications (for artists), Android App design and project management (for business majors), and directed independent study (for anthropology majors). The first course emphasizes a software component-based top-down system design approach for App development. The second course deals with tools for asset (graphic and animation) buildup and the aesthetic aspects in mobile application design. The third course focuses on business theories, marketing strategies, project management, and work breakdown. The fourth course advises anthropology students on research methods to observe, document, and (occasionally) advise the project teams. Students meet regularly, separated by disciplines, and a few times together during the class hours across the disciplines. They are encouraged to meet outside the class hours (during the lab hours) with their team members from the paired courses. The hope is to mix visual artists, analytically minded engineers, and venture-oriented business students together in small teams to catalyze innovation, with anthropology students as ethnographers and moderators. Since they have to form teams, we have a common assignment by the second week to post their bios at a common Blackboard community site. They will have the next three weeks to communicate with each other and determine the team make-up. We get involved if they are unable to form teams on their own; we help them make up their minds. During the lab hours (see below) the engineering and arts professors teardown our existing Apps. These are videotaped so others can watch even if they missed the specific lecture. Since the lab hours are attended by all of the students, independent of disciplines, it is an opportunity for interaction across disciplines.

Team Projects: By mid-semester (8th week), the students present their project ideas and get to work creating the applications. To facilitate this, the combined team is assigned three weekly common project assignments during 5th to 7th weeks: story-boarding of their App, technical mockup with Balsamiq[18], and prototyping with App Inventor[17]. The student teams make presentations to the professors and industry professionals F2F or online and are given feedback on feasibility (technical, artistic and marketing), uniqueness and useful links to find code and assets. After that , by the 10th week, they start on their final three weekly project assignments, on development of individual software components, graphic assets, and marketing plan; on integration and testing; and finally on a portfolio presentation to well-respected local BASE professionals to evaluate these Apps. The presentations (by the 13th week) includes a slide presentation by the team, a three minute promotional video, a live demo with a phone, discussion of the code and assets created, and a Q&A session. All the code, assets, documentation, & the project folder had to be submitted by teams for a grade to be posted (by the 14th week).

Video production: The artists and/or business majors take the lead in producing a short video to promote their team's work. They use the storyboard to create a polished presentation showing the features and uses of the mobile application. They used available video editing and effects software. See Videos[13].

Overview: The first half (weeks 1 to 7) of the semester is focused on discipline-specific summative assignments. During weeks 5 to 14 there are project-specific formative assignments, as cited above. During the second half, each week the students either have something in progress to show or we work out problems in creating the graphics or software elements. Case studies and tutoring are used extensively later in the course. Frustration and misunderstandings are to be expected. To quote an anthropology student from our Spring '12 semester *"oh, how the forced relationship can make a wonderful experience."*

Technology Plans: Based on student feedbacks, we are developing a virtual learning environment, with a suite of supporting tools to facilitate the work of team projects online[19].

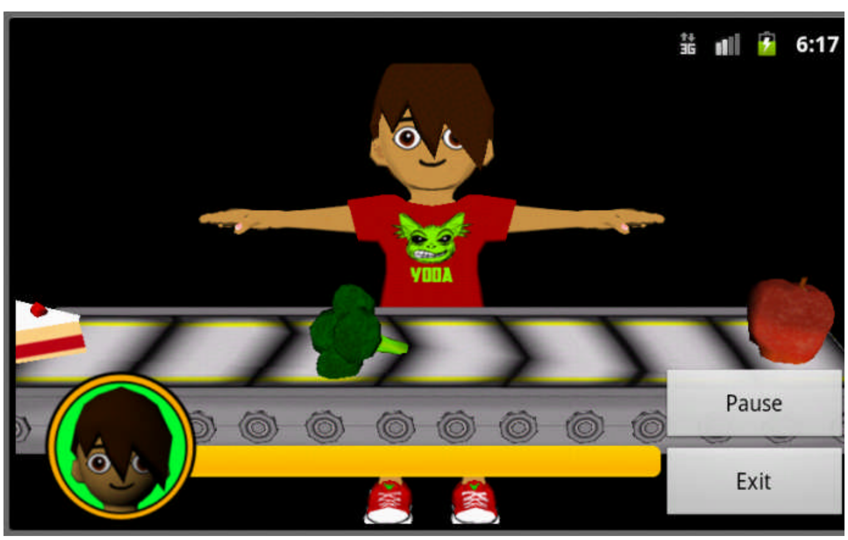

Figure 3: Healthy Kid App, developed by a group of undergraduate students in engineering and a graduate student in graphics (From the eLearning course taught by the first two co-authors during Summer 2012)

IV. Results:

A total of 450 students from various disciplines and levels (high school students to professional engineers) have undergone our program. Twenty five marketable Apps have been developed. Some of them will be marketed through the university in the near future. Five of our student teams have started small businesses to refine and launch their Apps (three of them are still viable). We have included three screenshots of student team Apps here (See Figures 3 to 5). More can be found online at our websites[5, 13]. About 200K global developers have visited FAU's Android site[5]. Three student led businesses are still viable. We get regular requests for graduates to hire/partner with. So, it has been a success from multiple perspectives. The remaining work is more on streamlining the operations and expanding to include all kinds of 'students' so true innovation can be facilitated.

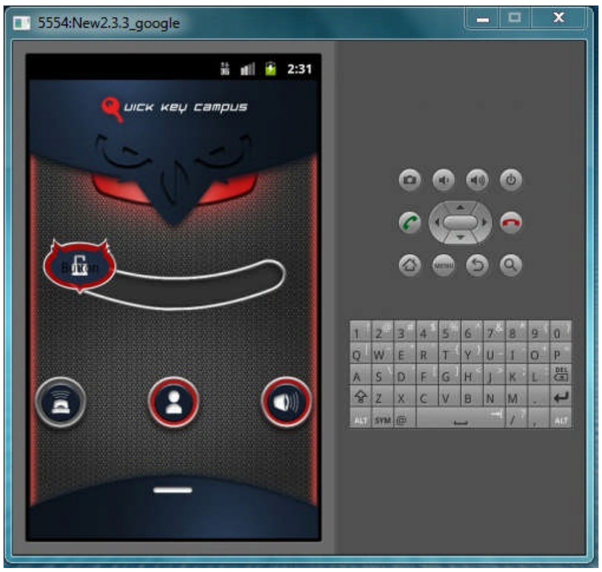

Figure 4: Campus Emergency Alert App, developed by a group of undergraduate students (8) from engineering, arts, business, and anthropology (From the 4-way course taught jointly by four professors during Spring 2012), now a business.

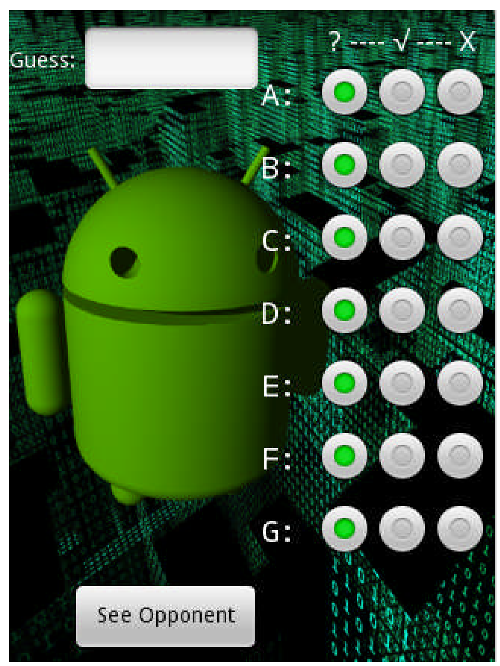

Figure 5: World Hacker App, developed by a senior engineering graduate student, based on a game developed by high school students in a previous summer session (From the Fall 2011 course jointly taught by the first two co-authors)

V. Challenges in Replicating Our Work:

We list here the problems we faced and our solutions that are working.

V. A Interdisciplinary Collaboration: There were three types of variability that had to be considered and overcome:

- Even within a college of engineering, it is difficult to institute multi-disciplinary efforts, since the skill set and backgrounds of both students and faculty members limit the quality and completeness of the project. To resolve this, we focused on reducing variability within the engineering domain[4] by the (a) use of a priori component development and design reuse, (b) use of prototyped Apps, (c) access to sophisticated API (application programming interface) libraries, (d) open source and local tech community support, (e) and clear separation of summative (with exam and quizzes) and formative evaluations (with the projects judged by a group of professionals). Graduate students helped with goal (a), while the work of previous semesters by other undergraduate students provided the prototypes for the current group. This met goal (b). Goal (c) was facilitated by Google's release of Android APIs and a free SDK (software development kit). Goal (d) was a consequence of both Google's Android effort and our own local effort to disseminate[5]. The last goal (e) resulted from iterative improvement during the first two years, and the authors' formal training in eLearning in the third year.
- If we now wish to bring students and faculty members from various colleges (arts, business, engineering, and content providers, such as nursing and urban planning) together, differences in discipline-specific behaviors, perspectives, and focus may undermine the goal. Even if professors worked together harmoniously, student teams may be impacted by individual discipline specific behaviors. We invited faculty members from graphics, social science and business to judge our engineering projects. This opened up discussions on the role of their expertise, and their desire to participate more actively, along with their students. After this initial exposure, these professors signed on to co-teach this semester long project course, thanks to the willingness of the Chairs and Deans to support such collaborative efforts. Because of this two stage involvement, the expectations were better understood and managed. This was an incremental approach, first with joint teaching between engineering and arts professors during the first year, which then extended to include a professor from anthropology during the second year, and eventually a professor from business in the third year.
- Forming cyber-teams brings its own challenges of eLearning[20] and information technology literacy[21]. A move to eLearning was necessary for two different reasons: Our University is comprised of six different campus sites in south Florida, and we also wish to scale it up so many joint collaborative teaching efforts could be underway, with different faculty groups. During the third year, we took advantage of training for designer/facilitator certification for eLearning courses. More details are provided later.

V.B Team Dynamics: During spring 2012, anthropology majors joined other undergraduate students to form BASE teams; they observed the team dynamics and cultural interactions. Six anthropology majors generated valuable feedback. This research approach follows the design based research (DBR) into learning, a practice-based research methodology [22]. Their enquiry brought to light a number of hurdles to overcome in the formation of interdisciplinary teams. Foremost among them was the coordination of activities and this coordination ramified from the top level (the professors) to the bottom (the students). The creation of teams depended greatly on communication among the interdisciplinary professors, on coordinating activities in such a manner that each individual discipline was proceeding in a manner that recognized the parallel work of others. We now maintain a faculty team site that allows us to synchronize our activities, but also provides transparency so students can be aware of the concurrent activities elsewhere[15].

Our work suggests that the creation of undergraduate interdisciplinary teams for the development of Android Apps is extraordinarily fruitful, not just for the sake of said Apps, but perhaps more so as an introduction to team work environments that programmers, animators, and marketers might find themselves in the future. Especially problematic, though, were the types of activities that students themselves developed for working through application, process, and design issues. Each small group appeared to understand the end product and their role (as programmer, graphic designer, or marketer), but each was uniformly bereft of knowledge or skills for working together in a coordinated, team-centered manner.

Their insight led to the following improvements in our Summer 2012 course: (1) Students did not want to form teams by the second week of the course - they wanted some time to 'settle down' and build connections. So, we now give them about five weeks before the above cited team assignments start. (2) Non-engineering students had to wait for the engineering students to complete a reasonably good prototype before they could proceed. Discussions (on promotional video, market niche, etc) of business majors and asset (graphics, animation, etc.) creation of artists were delayed as a consequence. So, we now have a quick prototype created with the App Inventor[17] that can then be used by business and arts majors to proceed on their own. This helps provide for early synchronization and goal clarification for the whole team. (3) Students could not meet their paired team mates from other disciplines. We now have scheduled 'lab hours' that they sign up for. These are two hours during the week when they are available online to talk to each other. The faculty members can schedule makeup or discussion sessions specific to teams/sub-teams during these lab hours. (4) Students were overwhelmed with both discipline specific assignments and team-wide project assignments. We now limit to five discipline specific assignments, with several others provided as self-assignments. (5) Some of the engineering students questioned the need for a team oriented project - they felt confident that they could develop all of it on their own. We invited industry professionals to give guest lectures and also to participate in team project evaluations. The teams hopefully now see that we are attempting to create a microcosm of the real world in these courses. The business students usually grasp the significance of this networking opportunity; but others have also benefitted). (6) The business majors also misunderstood university IP (intellectual property) policies, which caused much friction. Our Director for Technology Transfer has agreed to meet with the teams if they wish to get clarification. Further, the Director can also help them start their business at our university's incubation center.

V. C Scalability and Transferability: We want to facilitate other faculty teams interested in setting up similar courses. We will describe the stumble we had and how we are recovering from it. During Spring 2012 we extended our collaboration to include the college of business, without our staged process of due diligence. Apps developed clearly reached a higher plateau of real world metrics[9]; but personality conflicts were more prevalent at both the faculty and student levels alike. Fortunately, the three teaching professors on this paper were all enrolled during Spring 2012 in the same team eLearning designer/ facilitator certification course at our eLearning center. This was an intensive semester long course. This qualified us to teach the eLearning course last summer. Our eLearning center[23] fosters the "pedagogic integration of technology into the design of teaching and learning processes through collaborative efforts with faculty and other instructional technology personnel. It is where teaching, learning and technology intersect to meet the rapidly changing educational, social and economic environments in today's global society." The eLearning course[24] that we took used backward design of Wiggin and McTighe [25] and assessment techniques based on Angelo[26], Dunn[27] and Mueller[28]. We designed our joint summer course as a class requirement[14]. It allowed us all to appreciate the teaching and learning pedagogy. This also helped us with regard to faculty team dynamics, since we had the same vocabulary of teaching and learning outcomes, metrics, etc. Even then, we took a step back during summer 2012 to a two-way joint eLearning course, between engineering and arts students; we, however, did extend it to online teams. With the help of the instruction designers and our own anthropology research, we now have a clearer roadmap on how to develop a multiple-college course with BASE faculty and students[15].

VI. Discussion:
We discuss here issues beyond the course boundaries.

VI.A Accreditation: Our various BASE disciplines are accredited under AACSB[29], ABET[3] and SACS[30]. Though the individual keywords used vary, general themes in all these accreditations include group-based activities, authentic learning, problem solving, critical thinking, and systems-thinking. Starting from ABET's criteria 3 (a- k) on student outcomes, we have developed a framework of generalized learning outcomes to meet; apply STEM knowledge, research and analyze, design and optimize, work on team projects, solve problems, become ethical and responsible, communicate well, impact the community, learn life-long, achieve excellence, and gain professionally. These metrics will be tracked through post-surveys of the students, evaluation by the judging professionals, and long-term follow-up. They will not be used to grade the students, but to appreciate better the steps to be undertaken (such as new software tools for online learning and access to content, improved pedagogy, better assessment techniques, etc.) to achieve those outcomes.

VI.B The Engineering Student: We believe that any engineering student can participate in this course. The current course is listed as a semi-core course in the computer engineering curriculum and thus attracts only computer engineering majors. We, however, find that current engineering and computer science students have strong enough Java or programming background that we can help them complete the Apps. Consider that we have taught this to high school students and that a few arts students have taken our graduate course. There is a good reason for that: Android is rich in its library support; one can build great Apps fairly easily. Since the Apps are different, most students are willing to help each other. We also grade their work on an absolute basis which reduces anxiety in out-competing others.

VI.C Tools Used: For the engineering aspect, we used open source tools (Eclipse, Java and Android SDK) [4,10, 19]. Open source tools in engineering are free and are supported by a strong community spirit, which makes tutorials, code, Apps, quick help, etc., much easier to seek. Also, more complex Apps can be built on pre-designed building blocks (application programming interfaces or APIs, libraries and components), thus facilitating easy learning and rapid prototyping. We also chose the Android platform rather than the iPhone platform because of the market trend of steadily increasing market share (currently at 60% Vs. 25% for iPhone). This also implies that chances are that each team will have at least one or two students with the Android smart phones with the latest operating system. Our course flow got better as the Android infrastructure got more sophisticated. So, we are now well set to take advantage of a sophisticated platform. The arts professor has struggled with accepting open source tools and the componentization concept. Unlike the functionality goal of engineers, the artists take pride on aesthetic beauty and uniqueness of their creation. The open source tools in art are not as well accepted as are some of the commercial products (such as Maya, Adobe Photoshop, and Camtasia), which incidentally are available at low cost to educational entities. We are, however, slowly, making progress in incorporating open tools (such as Blender). The business tools used are easy to obtain and use.

VI.D Marketing of Apps: We wish to market Apps through our university to secure some funding to sustain the program. We wish to support two undergraduate students to help place a select few Apps on the App market, maintain our website, tag the App assets, fine tune the tools (yet to be developed), and generally improve the experience of students taking the course online and F2F. Further, generating some revenue will motivate student groups to work together and see collaborative opportunities beyond the university environment. This is not a problem for our business students, but is for engineering and arts students. FAU has set up an account to receive revenues from marketing the 25+ Apps in our portfolio. Some Apps will be marketed soon. We could not market the Apps so far for three main reasons: (1) Our university has had its share of turnovers. Decisions made by earlier administrators were reviewed by newer ones and the characteristics of the account changed. However, the good thing is that currently it is a robust structure that other universities can emulate. (2) Both software and hardware of Android smart phones underwent rapid evolution. As an example, we used Nexus 1 and Android 2.2 version in the first year; today, the versions to use are Nexus 4 and 7, and Android 3.1 and above. So, all the Apps developed earlier have to be mapped to newer hardware platforms with different screen sizes and resolutions. Of course, newer versions of the operating system do support all the earlier software; so, that was not a problem. (3) All the colleges involved noted a popularity trend and encouraged us to teach these joint courses more often. So, there were more coordination challenges to face and less time to market the existing Apps.

VI.E Marketability of Apps: The marketability was decided by the industry professionals who evaluated the projects as per a rubric[9]. The rubric may need some tweaking. A case in point: We surveyed high school students on the marketability of our summer 2010 Apps. It was interesting that some of the Apps that the adult judges considered not marketable were the ones that appealed to them the most. So, the 'marketability' as defined here is limited to the opinion of judging professionals. Putting all Apps on the market is not an option since much 'production' work will have to be completed to do so, as explained above. Also, some of these may have missing some of the business logic and full technology support. All these can be developed by student teams later on. However, we expect to present these 'prototype' Apps to other businesses and seek collaborations. This is a long term proposal that will take some time for our university to approve.

VI.F Availability of New Android Components: We finally have a good flow for our graduate students. They will be able to build useful Android software components that undergraduates can use. It may take two more iterations before the process is mature. Once that happens, the undergraduate Apps will be more powerful and less of prototypes/platforms. They will come close to having fully developed Apps ready to be marketed.

VI.G Entrepreneurship and Innovation: One may wonder whether our work can be considered to be innovative from an economic entrepreneurship perspective. Merely getting students to work on a real-world team project may not be considered to be entrepreneurial enough. Of course, we are facilitating the formation of student-led small business and it will take much better shape now that the college of business is a full partner. So, economic entrepreneurship is also evolving, judging from the formation of a few student-led small businesses. We are also collaborating with our local mobile technology consortium [31] in providing an avenue for student teams to meet and interact with business and professional leaders in the high tech arena.

We also analyzed our work so far to verify that we are on indeed on a path of successful innovation from yet another perspective, the wellbeing of a university. Denning and Dunham [32] define *innovation* as the art of getting people to adopt change. "Many inventions never become innovations, and many innovations do not involve an invention." They studied hundreds of innovators and distilled their practices into eight categories. They suggest that innovation is a continuing process of learning and practicing at increasing levels of skill. We have a good record on innovation, with several patents, royalties and industry collaborations among us. We have adopted their eight-stage process to combine change with existing practices and competing interests, and achieve successful innovation. The mapping shows that our work on smart phone Apps is proceeding concurrently at 4^{th} to 7th stages. We believe that if we continue to make progress under this frame of reference, outcome metrics for students (see above), the university (such as increased enrolment, publications, grants, and revenue) , and the society (such as small business formation and economic impact) will show improvements.

Conclusions:

We have developed a fairly repeatable and robust process to enable multi-college collaboration in developing potentially commercializable smart phone Apps for undergraduate students across different colleges. We have also instituted mechanisms to continuously monitor team progress and improve our teaching pedagogy to improve team and profession-oriented learning outcomes.

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