122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society
Paper ID #12421

Bringing a Viable Product to Investors Utilizing Senior Engineering Student Interns

Don Bowie P.E., Aurasen Limited

Don Bowie is a Systems Engineer with an extensive background in engineering design and management, labor relations, and various academic positions. His undergraduate degree is in Electrical Engineering from the University of Illinois, with a Masters in Engineering from Seattle University. Mr. Bowie is an honors graduate from The Executive Program at the Darden Graduate School of Business Administration, University of Virginia. His engineering and management background spans four decades in Aerospace Projects primarily at the Boeing Company. Career accomplishments include creating computerized systems for electronic design and testing, rocket orbital placement of telecommunications satellites, and the design and building of multi-megawatt wind turbines. His career has progressed from technical design engineer to large-corporation executive manager. His labor relations experience includes Vice President of the United States' largest professional/technical bargaining unit recognized by the Labor Relations Board. Don's academic career involves educational assignments which include teaching and developing several engineering and business related courses as a University Adjunct Professor, an assignment as a full time "Boeing Loaned Executive" from Industry to a University, and a multi-year tenure as an Affiliate Professor at Seattle Pacific University. Mr. Bowie is presently the CEO of a technical entrepreneurial start-up corporation which has sponsored and participated in six Engineering Capstone Projects and two engineering-intern sponsorships at California Baptist University. Don has had three United States' patents issued plus he was the primary author for three peer-reviewed academic papers which were published and presented at National Conferences. He is a Registered Professional Engineer and a Senior Life Member of the Institute of Electrical and Electronic Engineers.

Dr. Xuping Xu, California Baptist University

Dr. Xuping Xu is currently professor and chair of the Department of Electrical and Computer Engineering at California Baptist University. He received B.Sc. degrees in electrical engineering and applied mathematics from Shanghai Jiao Tong University, Shanghai, China, in 1995. He received M.Sc. degrees in electrical engineering and applied mathematics, and the Ph.D. degree in electrical engineering from the University of Notre Dame, Notre Dame, IN, in 1998, 1999, and 2001, respectively. In 2008, Dr. Xu joined the Gordon and Jill Bourns College of Engineering at California Baptist University. Between 2001 and 2008, he was an assistant professor and subsequently an associate professor in the Department of Electrical, Computer and Software Engineering at Penn State Erie, Erie, PA. His research interests include systems and control, hybrid and embedded systems, digital design, software/hardware enabled control applications, algorithms and optimization. He has published 18 journal papers, 39 conference papers, and 4 book reviews in the above areas. Since 2008, Dr. Xu has been serving as the assessment coordinator of the College of Engineering. He is a senior member of the IEEE and has been an associate editor on the Conference Editorial Board of the IEEE Control Systems Society. He also actively serves as a reviewer for a number of journals and conferences.

Dr. Anthony L Donaldson, California Baptist University

Dr. Donaldson is the founding dean of CBU's Gordon and Jill Bourns College of Engineering. Under his leadership the program started in the fall of 2007 with one additional faculty member, 53 students and 4 majors (BS CE, BS ECE, BS E, BS ME) and has grown into a college with five departments, twenty seven faculty with PhD's, and 515 undergraduate engineering students studying 10 Majors. Dr. Donaldson received his BS, MS and PhD in EE from Texas Tech University where his research was in the Pulsed Power area. He has published more than 70 conference or refereed journal articles in a wide variety of fields. His current interests are in engineering education from a Christian worldview perspective with an emphasis on leadership development, partnership with industry and cross cultural collaborations.

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Abstract

A four year teaching effort has been underway at the College of Engineering at a private university to develop, build and test a proprietary medical device. This ongoing project has involved six capstone projects consisting of 25 senior undergraduate students plus five independent intern students to do specific studies, analyses and building/testing assignments. It has been a team collaboration among members from five disciplines --- namely, the engineering professors (primarily the Dean of the College of Engineering and the Chair of the Electrical and Computer Engineering (ECE) Department), the CEO of a start-up entrepreneurial for-profit corporation, the owner and president of an electronic manufacturing company, a local medical practitioner (professional clinical audiologist), and a member of an initial capstone project student team. The first three years of this undertaking was presented at the 2014 ASEE Annual Conference and Exposition in Indianapolis, Indiana: *Teaching Engineering Project Management via Capstone Designs that Develop a Viable Product*. The essence of that presentation is contained herein.

This paper presents the work accomplished during the 2014/2015 academic year when it had been decided to transfer from a capstone based approach to an internship based approach for the continuing development of the medical product. Although the principles of project management and engineering design were well grasped by the students, lack of product completion plagued the capstones. The specific reasons for this capstone-to-internship shift, and the resultant progresses, are discussed in this paper.

End of abstract

Background

The first year of involvement consisted of three capstone teams (hardware, electronics and software) consisting of four senior undergraduate students each in a year-long undertaking (academic year 2011/2012). An engineering model of a user-programmable hearing aid system was designed and its construction was undertaken. However, at the end of the academic year the system was not operational and no significant clinical testing had taken place. Being the College's first undertaking of this magnitude, numerous improvements were incorporated into the pedagogical approach. A smaller capstone approach with two capstone teams, of four students each, was then undertaken the following academic year (2012/2013). These teams developed new hardware, modified the software, and made minor improvements to the original design. However, again no fully constructed system was completed and little clinical testing was accomplished. After a review of the two teams' efforts, additional pedagogical improvements were incorporated and it was decided to involve one five member capstone team to continue the project for the following academic year (2013/2014). Once again a completed system was not forthcoming and only limited testing was undertaken. The original five-discipline professional team was still actively involved; however, those individuals had serious doubts relative to continuing the effort. The primary objective of an industrial project is to produce a functional product or service. This was not being accomplished. Therefore, it was questioned if these capstone projects were satisfying the objective of providing a "first job" experience. In the summer of 2014, it was decided to do an evaluation of the situation and either terminate this collaborative effort or significantly change the approach.

The Evaluation and Findings

In our 2014 ASEE paper it was stated that to some individuals a "cultural chasm" appears to exist between the academic world and the professional engineering environment, in that often employers that hire recent engineering college graduates perceive that those graduates have not been properly prepared for the engineering profession. With this thought in mind, it was decided to investigate whether we were mitigating or contributing to this phenomenon in the capstone projects – which are intended to emulate engineering projects in industry.

An investigation of the conditional state of the products from the previous three years of capstone efforts was undertaken. The basic designs were evaluated, followed by a physical inspection of the constructed hardware and electronics. The software code was evaluated for operability. The Engineering Dean and the ECE Chair further questioned why several other capstone projects did not achieve their intended functional objectives.

The corporate sponsor's CEO personally did a very detailed evaluation of the electronic design. He analyzed the circuitry for basic design, component layout and construction robustness. The basic design was found to be fairly good with only a few questionable design decisions by the students. There were no "fatal faults" (a fault that is correctable only by a total re-design).

The manufacturing president personally evaluated construction of the electronics. His findings were that the construction was very poor, including one circuit card that had to be discarded. The overall hardware layout and system container were designed without full consideration of the operating environment but, here also, there were no "fatal faults."

Two then-student members of the initial capstone team (2011/2012) offered their help to identify and correct some technical problems. Both of these individuals are now employed in the engineering profession with one individual having obtained an Engineering Master's degree.

An engineering software intern was hired in the summer of 2014 to map and evaluate the software. The resultant software map showed that a basic logical code structure existed but that numerous "bugs" and unfinished code modules kept the code from being operational. However, once again no "fatal faults" were observed.

An overall consensus was consequently reached: *Those efforts related to what the students had studied – hardware design, electronic design and software design – was* *relatively well done. However, a significant problem existed in the physical implementation of those designs.*

In view of the above, we were presented a quandary.

The Quandary

Engineering is the professional practice of utilizing proven scientific principles, and applying those principles to produce practical and useful products or technical services. The scientific profession involves the determination of how the universe operates and describing that operation so that such knowledge may be utilized by others, including engineers. The question we had to ask ourselves was: Are engineering colleges producing individuals who understand the principles of basic design, but not the implementation of those designs, i.e., the mistaken belief by many engineering employers that engineering colleges are developing scientists, rather than engineers. We do not believe this to be the case.

In the past it was common industrial practice to have the engineering department complete a design and "throw the resultant drawings over the fence" to the manufacturing department. The discipline of Manufacturing Engineering, the growth of software development (which has minimal manufacturing), and design/build teams in industry has mitigated the engineering/manufacturing (design/build) "cultural chasm" in industry. But we must ask ourselves: Does this perceived "cultural chasm" (between design and build) exist in our engineering colleges.

These issues have been addressed at the Engineering College in context by making every graduating engineering student complete an engineering internship of at least 200 recorded hours. Therefore, with the agreement of the involved five-discipline professional team, it was decided to continue the project; but by using student interns rather than using capstone project teams. An arrangement was agreed to: The non-faculty portion of the professional team would provide "hands on" technical direction and support; with the Engineering College faculty having controlling oversight – the students are still ultimately answerable to the professors.

Observation

The following items highlight pertinent observations by the involved engineering faculty and the supporting sponsor.

Murphy's Law: "If it can go wrong, it will." And almost every project has something embedded that can go wrong ("The best laid schemes (plans) of mice and men / often go awry." – Robert Burns). The students seem not to be aware of Murphy's Law. Some of this comes from the optimism and enthusiasm of youth. But it produces the thinking: "If I do a good job of design, it will work." There is no contingency, work-around or mitigation consideration proposed. This often leads to last-minute panic work sessions and the resultant generation of student status-presentations where it's stated: "We're only one problem away from complete success." This has been addressed by the sponsor making an issue of "planning for numerous initial failures, but expecting to achieve ultimate success."

Team Effort: "An identification and organized deployment of tasks." All too often the Team Leader becomes the primary worker. It is too easy, for both students and individuals in general, to "let George do it" and thereby, destroy the team morale. The Engineering faculty has addressed this condition by making time logs a grading criterion. The corporate sponsor is not local and recognizes that his absence has been a definite shortcoming. Electronic communications have been increased between the sponsor's CEO and the student interns to mitigate the distance problem because many students have a propensity to be non-proactive on their own volition (possibly a maturity issue). The CEO now comes to the Engineering College for student work sessions rather than for formal presentations. Saturday-morning four-hour work sessions (including attendance by several of the professional disciplines and all the student interns) have been exceedingly productive. The CEO employed an available software student to assist in those technical areas where the CEO lacked a detailed technical working knowledge.

Meaningful Time Management: "The efficient use of the one item that is universally and equally available to everyone: 24 hours a day." It is often easy for students to procrastinate their work on capstone projects because immediate due assignments exist in their other classes and the capstone completion date appears far off. On an internship-based project the 200-hour mandatory requirement is traceable and the percent completed (hours expended) is easily measured. Moreover, the student will realize that without 200 hours of participation he/she will not have completed all the graduation requirements. Another ineffective use of time is students' tendency to use "free tools" because of cost considerations. Industry is very concerned about labor cost (time) and cannot afford to deal with unsupported, and often non-robust, tools. The use of such problem-plagued tools was a major impediment to obtaining an operational system. The sponsor's CEO has talked to the students and emphasized that "time is money" and "do not hesitate to ask for help" – especially utilizing the supporting professionals – plus looking for other ways to successfully proceed when faced with a stalled task (think out of the box).

Problem Handling: "The skill of diagnosis and subsequent corrective actions that is efficacious." In college engineering labs effective student laboratory experiments need to be set up to function correctly. The significant effort to obtain this correct functional operation has been accomplished by the instructor in order to provide a good learning environment unhindered by error-caused distractions. On capstone projects correct functioning is the responsibility of the student – a task most engineering students are not well equipped to handle. An additional significant cause of technical problems is that basic construction knowledge is usually lacking among the students. Involved assistance from the supporting professional individuals helps both situations significantly.

Conclusion

The internship effort to produce a working system is well underway at the time this paper is being written. ***The system has been made fully operational and entry into user and clinical testing is imminent.*** A key observation is that the interns seem to be divided between those who can be counted on to keep “marching forward” without ongoing prodding, and those that can easily find outside distractions. In industry that condition is often handled by the “slackers” becoming candidates for participation in “workforce adjustments.” A less harsh method is utilized in education because the student is the customer, whereas an employee is a paid “hired hand” subject to the pleasure of their employer. At this Engineering College the interns’ time logs “tell all” and force all interns to identify their efforts and expend equal time (200 hours).

Full professional team participation (faculty, sponsor, manufacturer, practitioner and initial-capstone members) in technical oversight and in progress reviews has been ongoing. These professional individuals will unhesitantly play the role of “bad cop” by pointing out shortcomings when results are not forthcoming – that is what they do every work day.

Results to date have been very encouraging. Many software glitches and bad electronic circuits have been addressed. Making the student aware that they are participating in an “industrial environment” seems to be productive. Multiple visits to the manufacturing president’s facility and to the practitioner’s office have taken place.

This internship-centered approach is taking place during the school year, rather than during the summer when most internships are underway. The bad news is that the students must struggle with balancing their internship responsibilities and their normal student class responsibilities. The good news is that summer interns are often under the leadership of non-supervisory employees who cannot spend significant amount of time with them; whereas, the interns on this undertaking have ready access to senior professional individuals.

A unique and very significant aspect of this four year effort is the persistence that the professionals – the engineering faculty, sponsor’s CEO, the manufacturing president, the clinical practitioner, and the initial capstone members – have shown. It is extraordinarily outstanding. And a feeling exists that we are narrowing the “cultural chasm” that is perceived to exist between engineering colleges and industry by utilizing the procedure of a capstone project followed by a subsequent-year intern team that has significant technical and industrial support to “make it work!”

Our recommendation to the engineering teaching profession is to not pass an uncompleted capstone project to another capstone team the subsequent year. We did that twice and made only marginal progress both times. However, when we passed the unfinished capstone project to an intern team (with significant professional design, manufacturing and provider support) the product was made operable and we have now initiated the sequence of provider verification, field testing, and clinical validation, i.e., a functional engineering prototype was produced and operational testing has commenced.

An engineering capstone project is a teaching tool meant to culminate an engineering education (which consists of scientific understanding, technical design and results presentation). This educational task is well handled by the professional academic engineering community. Concerning the subsequent task of bringing a completed design to a fully functional engineering prototype that accomplishes an intended purpose, we found it best handled by an intern team with faculty oversight in conjunction with significant professional industry support. Engineering faculty members seldom have the available time, or they may lack the manufacturing experience, to provide the in-depth effort it takes to bring an engineering design or lab unit to an operational manufactured reality – yet this is a capability that industry desires of recent engineering graduates. In our case we found that using, as interns, students who had not completed their required internship hours via industry employment were especially helpful to fill in such experience.

The Bottom Line

It is our belief that the thirty engineering students that have been involved in this four year undertaking have received a significant pragmatic introduction to the engineering profession – the transition from the structured and knowledge-gaining world of academic engineering education to the chaotic and demanding world of the engineering profession. It is also hoped that the resultant successfully developed medical device will find a place in helping hearing impaired individuals to better "Listen to Life" (the registered trade mark of the sponsoring company). We know that all the individuals involved – engineering faculty, sponsor, manufacturer, practitioner, and students – have personally gained due to their respective involvement in this "learn by doing" departure from the usual engineering student's "undirected" introduction into the engineering profession.