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A Successful Engineering Program-Corporate Partnership

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Abstract

This paper addresses the benefits and challenges of creating a customized ABET-accredited engineering program and presents a case study of such a development for a large multinational company. A brief review of the engineering program's structure is provided as it plays an important role in being able to successfully adapt the degree to the needs of the company. The case study explains the university-company planning process, how criteria were developed for the program design and customized aspects of the degree program. The case study also explores the difference in program expectations of the industry partner from those of the University, including student preparation, and how these differences were resolved. The case study shows how the planning process moved from higher levels of planning to successful implementation. Finally, nuances related to offering such program in an international setting and related engineering education capacity building efforts are briefly discussed.

Introduction

It is often the desire of large companies and other special interests, e.g., emerging country educational agencies, to have engineering programs tailored for their employees or citizens. Such tailoring enables curricula and student outcomes to be specific to a particular industry's operations or the country's needs, e.g., engineering education capacity building. While there can be many advantages to creating such programs based on a program offered via a traditional model by a University, there are also significant challenges. These challenges can include issues involving ABET accreditation as well as the inherent flexibility needed to provide sufficient adaptation of the existing program to meet the company's needs. Such needs include the desire to accelerate delivery and to accommodate the work and production schedules as the program is delivered to employees even as those employees remain on a full-time work schedule. While customized programs are found, often they are online offerings of degree programs.[1, 2] Another example is where a consortium of major oil companies funded the creation of the Petroleum Institute in 2001. The goals of the Institute included educating United Arab Emirates nationals in various fields of engineering and required some customized development of content.[3]

The College of Technology and Innovation at Arizona State University offers an Engineering Accreditation Council (EAC) of ABET-accredited Bachelor of Science in Engineering degree. The degree's curricular structure includes an engineering foundation in the first two years and primary and secondary areas of focus in the third and four years. The program utilizes a project spine, with project classes every semester of the curriculum, with an explicit emphasis on the students gaining professional skills as they progress through the curriculum, as recommended by multiple engineering education studies.[4, 5, 6] The program utilizes a 120 semester hour curriculum and is structured to satisfy the "general" ABET criteria (but not any program specific criteria such as electrical or mechanical). The curriculum also includes nine hours of unrestricted electives, which are often useful when a student transfers into the program since credits can count towards the degree where other engineering programs might have to reject the credit.

The primary focus area includes significant upper division project experience with six semester hours of project-based credits in the 20 credit hours within the focus area. The 20 credits in the focus area do not include eight hours of multidisciplinary capstone design, which are considered core content for the degree. The secondary focus requires 12 semester hours of coursework in the chosen secondary focus area, with no project hours included in these 12 credits.

One feature of this structure is that the secondary focus area need not be inside engineering (EAC of ABET accreditation requirements are met without these 12 credits). For example, by combining the secondary concentration with unrestricted elective hours and humanities/social science hours, a student could embed any number of subjects within a B.S. in Engineering. Of course, the secondary and electives could also all be engineering, a choice that many students make. Even in the latter case, students can mix and match topical areas, e.g., mechanical and electrical or mechanical and manufacturing, or build greater depth in a given focus area, e.g., mechanical and mechanical. This flexible degree structure, its free electives and the primary and secondary focus areas, proved to be key to meeting the company's needs.

Initial Planning

The company, which is not identified at their request, has a large work force in the Phoenix metro area and has long supported continued education of its employees, especially engineering education. Many of its employees do not have a bachelor's degree in a technical area yet the work they do is highly technical. Those employees that pursue advanced education while working full time take years to complete a bachelor degree, often close to 10 years. The company, when looking at their long term engineering needs, decided that they needed an accelerated schedule that would allow selected employees to keep working full time yet earn an engineering degree in a much shorter time span. The company approached two Universities about fielding such a program, which would not be delivered online or via distance education mechanisms. However, none of these institutions were willing to commit to meeting the company's needs. It was at this point that the company contacted the College of Technology and Innovation and after several meetings, the College of Technology and Innovation (CTI) accepted the challenge of providing its Bachelor of Science in Engineering degree in a customized manner. The customization envisioned included the schedule and manner of course offerings as well as a new primary focus area fitting company desires.

At this point, the company representatives and College administrators had a four-hour planning meeting in late January of 2012 to develop the roadmap plan to deliver an accelerated version of the final two years of the engineering program, to be delivered on the company's site. At this point in the planning process, it was assumed that many of the target employees would have a technical associate's degree or had started an engineering degree as a part-time student. The target was a program implementation with a pilot program of 30 – 40 students in fall semester of 2012. If successful, the program could be expanded to company employees in other states, but still in a face-to-face modality. The team had less than six months to plan, organize and implement the program.

The roadmap planning meeting produced an Excel spreadsheet in a Gant chart format with over 75 work items on it. The spreadsheet also included color coding reflecting responsibility for the task (company or College), as well as major milestones. The significant organizational work streams included: definition of curriculum (and new focus area); gap closure (remediation of students that were not ready for the second two years of an engineering curriculum); development of a financial model to support new development work; company resources to field the program (both recruitment and employee absence from work); student recruitment, evaluation of their academic preparation and admission to the University; and the curriculum delivery plan (how to deliver the courses within an accelerated, block schedule). To aid in completing all of these tasks, a weekly meeting, usually a phone conference call, was arranged between the company representatives and the College representatives. These meetings proved to be critical in helping the team meet its timelines by open communication and rapid decision making.

In recognition of the importance of its employee's participation in this program, the company had decided to provide paid time from the normal work schedule for its employees attending classes. This paid time off would be matched by the employees giving up a scheduled day off to spend in classes. Thus, the employees would have one full day a week for classes. In addition to this day a week, employees would be scheduled for full week (five days) of intensive class time each quarter. Due to the monetary commitment involved, the company was going to restrict participation in the program. However, any employee that did not gain entrance into the accelerated program could pursue educational programs via the normal academic support model fielded by the company to all its employees.

Customized Program Design

The College began to analyze if there was sufficient contact hours to offer the technical content of the second two years of the engineering program in two years, including summers, with this schedule. The analysis showed that it was possible to offer a two-year completion path for employees, using the full day of class time each week and five days each quarter. The University's online offerings of general studies courses, typically taught in a seven and half week schedule would be utilized on an individual, and as needed, basis by the employees for general studies courses, separate from the block schedule of class offerings.

The College staff and administrators developed three curriculum-offering models for review by the company. The differences among these models centered on how many weeks in the summer were used for classes and the weekly work load on the students. Also, we investigated whether less than one block week of instruction per quarter would be sufficient since these weeks were a significant cost to the company. All models accounted for the number of hours of student effort, both in class and out of class, required to meet state regulatory requirements.

The team achieved its planned milestones and by late March had developed a model curriculum (both the core program offering and the new focus area desired by the company), the financial model, and an approach to selecting employees and evaluating their academic preparation for the program. In April, the program was rolled out to the company's employees and information sessions were held at the company for the employees using a jointly developed presentation. It was pointed out to the employees that gaining admittance to the program was a multi-tiered process. First, the company had to decide if the employee would be allowed to participate. This decision was to be driven by internal factors, including things like past performance of the employee, and the College had no role in this internal decision process. Once the company tentatively accepted the employee into the program, the employee's academic preparation and ability to be admitted to the University had to be ascertained. Initially the company wanted to restrict program participants to a cohort of employees that were ready to begin the second two years of the engineering program. However, sufficient concern existed that there might not be enough students to make a viable cohort (a number set by the College at 20 to 25), that final decisions on inclusion in the program were held until academic preparation analysis was complete.

The academic preparation of the program's participants proved to be a significant task for the College staff. One difficulty was that this evaluation was preliminary to the student admission process. This evaluation, while based on transcripts, was unofficial with the goal of helping the College and company make decisions about gap closure efforts and employee inclusion in the program. Thus, the College staff evaluated the previous academic work of the employees by looking at the categories of previous engineering-related coursework and critical math and science courses, assuming that non-critical course work, e.g., lower division general studies, could be accomplished outside of the accelerated program. Over a period of three to four weeks in April and early May, over 100 people submitted a variety of transcripts for review.

The analysis of academic preparation showed a complex situation. First, there were a few people fully prepared for the start of the second two years of the engineering program. Of the remaining applicants, a wide range of preparation existed. While a number of the people had completed at least some of the science classes, many were lacking mathematics courses with approximately half having some portion of the calculus sequence completed with the other half needing prerequisite courses for calculus. The latter group was not considered further for the initial cohort but was counseled to start working on the mathematics courses in preparation for later cohorts.

To make the program work within the two-year delivery target for the engineering program's content, it was necessary for the students to have, or be able to get on their own, some engineering coursework. Due to the flexible nature of the BS in Engineering degree, up to 19 hours of previous academic work that was technical, but not necessarily EAC of ABET-accreditable coursework, could be counted towards the degree. However, it was necessary for student to enter the final two years of engineering content with at least seven hours of accreditable engineering coursework or obtain it before graduation to make the credit count sufficient for graduation. But, the content of the final two years of engineering content was structured to avoid specific prerequisite requirements to allow the widest possible range of student participation.

Gap Closure Plan

After discussion, the team decided to mount an aggressive gap closure program that would start in the summer 2012 term and extend through the summer session of 2013. This plan had the potential of preparing over 50 students for the fall 2013 launch of the accelerated last two years of the program. This gap closure program had to be approved by company management since it effectively added a year to the internal support of the cohort. In the longer term, it was assumed that future cohorts would be able to move directly in the accelerated two year program since they could spend the intervening time completing the necessary lower-division subjects.

As the program's gap closure launch drew closer, discussions ensued about the location of the classes. While the initial thoughts during the conceptualization phase were that courses would be taught at the company's site, the team decided instruction would be more effective if the classes were offered off site. The logic was that employees had a much higher chance of being pulled out of classes due to plant operational needs if they remained at the site. Also, it was found during the gap closure courses that the students felt much more connected to the program and Arizona State University by attending classes on campus. A minor advantage was created in that the instructors would not have to travel and normal classroom facilities were used. However, using campus facilities presented a bureaucratic challenge for the College as the Wednesday block schedule fell outside the norm of University scheduling. This issue was resolved due to recognition by the University administration as to the high profile and importance of the program being successfully offered to the industrial partner.

The College of Technology and Innovation has a variety of academic programs/units within it, an unusual characteristic in a large research university. Of importance to the initial success of the gap closure program was the Applied Sciences and Mathematics Department, which offers chemistry, physics and mathematics courses. Thus, we did not have to cross college boundaries to arrange the special schedule necessary for the customized course offerings. Also, since we wanted to make sure the program and its participants experienced a smooth and productive start, the best instructors in the math and science area were assigned to teach the courses.

This combination of factors was very important in the initial offering of the gap closure program. This course was MAT 265, Calculus for Engineers I and was taught in the second 6 week session of summer. Thus, the three credit class was delivered in six all-day Wednesday sessions. The class was success but only because the students were mature and highly motivated and the instructors (a team of two were assigned to the class) were both skilled and dedicated. Students created ad hoc study groups at the workplace that met after work shifts to help cope with the pace of the material presentation. Also, at least one of the instructors held office hours at the work site to help the students.

The gap closure course offering and enrollments are shown in Table 1. The classes offered in fall and spring utilized a split day schedule. In this manner, using fall semester as an example, half the day was spent on Calculus and half on Chemistry. The chemistry lecture and lab are included in those course offerings.

Session	**Course**	**Enrollment**
Summer II, 2012	MAT 265, Calculus for Engineers I	12
Fall 2012	MAT 266, Calculus for Engineers II CHM 113, General Chemistry I	20 23
Spring 2013	MAT 275, Differential Equations CHM 116, General Chemistry II	25 26
Summer 2013	PHY 121, University Physics I: Mechanics EGR 280, Engineering Statistics	

Engineering Program Delivery

In the fall 2013 semester, the cohort, expected to be around 40 students, will take engineering classes and linear algebra. A part of the scheduling complexity was the combination of lower division and upper division courses needed due to the mix of students within the cohort. Thus, for the fall semester, students will be enrolled in four classes, as shown below. Originally, all courses in this semester were to be engineering topics with the final mathematics course in the following spring semester. However, due to student input about their desire to keep the math courses adjacent to each other, the linear algebra course was moved to fall semester.

EGR 216, Fundamentals of Engineering I, 3 credits (first half of the semester)

EGR 217, Fundamentals of Engineering II, 3 credits (first half of the semester)

EGR 301, Fall Concentration Project, 3 credits

MAT 342, Linear Algebra, 3 credits

With this load, the students will busy with both course work and maintaining their work-family-school life balance. The block schedule of class presentation allows course sequences like EGR 216 and EGR 217 to be taken in the same semester. The fall concentration project class is planned to take advantage of the nature of the program and is cohort-offering structure. Essentially, the intent is that the students will be working on a project based in their workplace. While students all work at the same company, they are often in different specific work areas so the project teams will retain the mix of backgrounds typical of project teams utilized in the normal offerings of the program. Due to intellectual property issues, the "faculty member(s)" for the class are likely to be company engineers. However, these instructors will have to meet all the requirements of the College for any part-time faculty member teaching one or two classes.

The following spring, summer, fall and spring semesters will follow a similar load scheme. As an example, the spring semester of 2013 includes a physics course, two focus-area courses and an engineering project course. The team agreed that during the summers only one session, with one course covered in the six Wednesdays, would be scheduled to allow employees to have opportunity for summer vacations with their families.

Cost of the Program and Faculty Issues

As implied earlier, the company is reimbursing the costs of attendance at the University for its employees in this program. Initially, the company provided limited funding to offset the CTI staff time needed to do the analysis of the academic preparation of the employees expected to be program participants. The company also agreed to provide development funding for new courses in their desired focus area, a new offering by the BS program. This modest rate per class will be used to cover the costs of developing the new course content, including the customization for the block schedule of delivery. Otherwise, there are no additional costs levied to the company for the program delivery.

The faculty involved in delivering the gap closure classes were both challenged and invigorated by the need to deliver courses in the block format. The first class offered in this format was the first semester of calculus, taught in summer session with only six class meetings, and the faculty had only a two-week preparation time before the class began. It was team taught by two highly regarded faculty members that proved to be willing to make significant efforts to ensure the success of the class. Students formed study groups, often meeting at the work place and the faculty responded by holding office hours at the company site. Such efforts helped the program to have a successful start.

As any engineering educator realizes, offering a different form of an ABET-accredited program can raise accreditation issues. The company, since it was requiring the program to have such accreditation, and the College have a mutual interest in ensuring the program offering does not harm the program's existing accreditation status. However, since the existing program is simply being offered in a different time schedule, with no real difference in delivery method, e.g., it is still face-to-face and on campus, such issues are minimized. However, the program's assessment processes must be accomplished and the program's faculty must maintain oversight of the program. Since the bulk of the engineering content will be delivered by the program's faculty, the latter issue should not be significant. However, the use of company engineers to oversee projects and the intellectual property issues that may prohibit project technical content from being revealed to the program's regular faculty has sparked discussion. Fortunately, by the program's assessment and continuous improvement plan, the significant course outcomes that need to be assessed in the project courses do not rest on the technical specifics but on the professional skills demonstrated by the students. Thus the intellectual property of the technical work can be protected. This realization seems to have addressed initial concerns about this issue.

Recommendations

Based on this experience, the following recommendations are made regarding successfully offering tailored engineering programs that meet the desire of large companies or other special interests. First, extensive planning and communication involving the college and company stakeholders are critical. For instance, the four-hour planning meeting establishing the steps and milestones required to begin offering the program was critical. Driving the plan forward with the weekly meetings with stakeholders and holding various parties responsible for the actions needed during each week is not always typical within the academic environment but was vitally necessary for project success. Also, it is important to recognize that, in spite of such planning, unforeseen issues will arise but the team can successfully navigate through those obstacles. For instance, after the gap closure analysis was completed, the inaugural program offering was extended by a full year.

Program flexibility is critical to being able to offer the program and accommodate the needs of the company and its employees. Many engineering programs have a curriculum that is extremely prescribed with few available electives within it. This condition has often resulted from programs having to reduce their total credit hours to 120, usually the result of a state mandate. But, such rigid curriculum can prevent programs from being able to meet the needs of company or satisfy someone that does not fit the prototypical mold of an engineering student. Engineering education studies have also recommended an increase in flexibility within engineering curricula.[4, 5]

Faculty willing to offer content and coach non-traditional students, e.g., those already working in technical positions, in modalities that are not the standard 50 minute lecture format are critical.

Faculty rapidly become the face of the program to the students and company and if those faculty are not supportive of the non-traditional course structure and students, the program will fail.

Finally, as illustrated by the refusal of two other universities to work with the company, it is necessary for college and program leaders to be willing to consider developing unusual offerings of their programs. While ABET accreditation may require careful action, it does not preclude such offerings. Just the process of thinking about program offerings that are atypical leads to fruitful conversation and challenges to conventional thinking about offerings. For instance, the customization reported above has taken interesting turns with regard to international offerings.

International Nuances

The paper has thus far dealt with a customized offering of the engineering program within the local environment. However, this project initiated conversations about utilizing the flexibility of the BS in Engineering program in a foreign setting. The program's adherence to many of the tenants recommended by recent engineering education studies (e.g., use of a project spine, flexibility so students can follow their passions and emphasis on the professional skills) make it attractive to industries with significant operations in foreign countries that desire a skill set in new engineering graduates that is somewhat different from that provided by traditional, theoretical in nature, discipline-focused engineering programs.

US-based engineering programs being offered internationally is not new to engineering education and has led to US-based institutions developing whole campuses. Texas A&M in Qatar is such an example.[7] However, such a large undertaking is not always possible and may not scale to meet the needs of the multinational industrial base in the host country. In some cases, there are existing institutions of higher learning in the country but their offerings may not have the desired content or the characteristics deemed necessary by the companies. In other cases, a country may have a national plan or desire to offer high quality higher education to its people but both industry and the country's educators may recognize that significant yet fundamental hurdles exist, as discussed by Baltimore and Estes with regard to Tanzania.[8]

There are two international scenarios of interest to customizing engineering degrees to meet company needs. One scenario revolves around a country or company wanting to have a US-based degree available to its citizens or employees at an international location. The scenario may be complicated in that the country may still be developing its educational infrastructure. In this case, Arizona State University is responding to an interest by Vietnam being driven by US-based companies with large operations in the country. In Vietnam, there is a significant higher education infrastructure in place with multiple institutions offering engineering programs, including what US-based programs would equate to as associate of science degrees and bachelor degrees in engineering. However, as noted by Simon with respect to China[9], while these institutions may provide a good basic engineering education, graduates often have only theoretical engineering knowledge and lack creative and critical thinking skills necessary for innovation along with a lack of professional skills like teamwork and communication.

As an example, Arizona State University and the Intel Corporation recently renewed a joint commitment to help improve higher education and technology development in Vietnam.[10] With the Vietnamese Ministry of Education and Training, the partners agreed to continue and expand the Higher Engineering Education Alliance Program (HEEAP). Established in 2010 with an initial $5 million grant from the United States Agency of International Development (USAID) and the Intel Corporation, HEEAP's mission is to modernize teaching and learning methods in Vietnam's schools of higher education as a way to support economic development in the country by advancing engineering education to prepare engineers to support Vietnam's growing high-tech industry.

As a side development to the larger HEEAP project, initial discussions have occurred about "importing" to Vietnam Arizona State University's flexible BS in Engineering degree discussed above. While the decision to field the degree in Vietnam has not been made, the CTI administrators have begun thinking about how this could be done. Given relationships developed due to the HEEAP, it would be expected that the degree would be offered in conjunction with one of the Vietnamese Universities. In addition, to the complexities of offering the degree in the customized mode as being done locally in the US, additional complexities with regard to ABET accreditation have to be resolved. For instance, Criteria 6, Faculty[11], states that "The program faculty must have appropriate qualifications and must have and demonstrate sufficient authority to ensure the proper guidance of the program and to develop and implement processes for the evaluation, assessment, and continuing improvement of the program, its educational objectives and outcomes. The overall competence of the faculty may be judged by such factors as education, diversity of backgrounds, engineering experience, teaching effectiveness and experience, ability to communicate, enthusiasm for developing more effective programs, level of scholarship, participation in professional societies, and licensure as Professional Engineers." Demonstrating compliance with these and other ABET requirements for an engineering program being offered on site in Vietnam would not be simple.

Conclusions

In summary, the customized program to deliver the College of Technology and Innovation's BS in Engineering to a major industrial partner has proven to be successful. The first three semesters of course offering have shown that the schedule is workable from the college/company/student point of view. Although students are working hard, they appear to be able to maintain a school/work/family balance while they recognize that the extra effort and sacrifice now will benefit them upon completion of the program. The company representatives on the program implementation team have been pleased with the program's delivery model and the efforts by the University to work towards a customized program that will help meet their long term engineering workforce needs. Also, the experiences gained by developing and implementing the customized delivery of the BS in Engineering program, as detailed above, and working with Vietnamese via the HEAAP project serve as an excellent foundation for international expansion.

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