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Development of Sustained Academia-Industry Partnership A Successful Model and Two Case Studies

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Abstract

Increasingly, engineering educators recognize the importance of preparing our students in not only technical knowledge and skills but also in professional components such as leadership, management, teamwork, ethics, and professional responsibility so they can be successful in their careers. Few of these elements can be simulated effectively in a traditional academic environment and the participation of engineering practitioners becomes critical. Similar to most engineering programs, we have achieved this through the involvement of our advisory council members in this capacity and this paper presents our experience in developing an academic-industrial partnership over the years. The relationship starts with the integration of these industry leaders into our program's continuous improvement process, including ABET accreditation assessment, the sponsorship of senior capstone design projects, and other educational activities. The development of the partnership has further extended to dual-degree BS-MS internship and project support, research collaboration, fellowship sponsorship and involvement with an international exchange program. In this paper, the faculty industry liaison and two industry leaders will provide an overview of these activities and their impact on our program. We focus our discussion on the aforementioned successful model with two companies, Cummins Inc. and Danfoss Turbocor Compressor Inc., which have different types of affiliation with our program. Cummins is a Fortune 200 global company with no geographical or strategic connection to our school initially. Over time, a long-lasting relationship has developed. Turbocor is a manufacturing company located locally while active globally with state-of-the-art technologies in its industry and setting a new trend with their global products. From the academic program perspective, the partnership has provided real-world experience to our students, relevant advice on emerging industrial trends in workplace, and a professional network for our faculty and students. From the industrial partners' viewpoint, they can encourage needed curricular renovations, leverage an academic program's research and development expertise, and gain direct access to the most motivated and capable graduates for potential employment.

Introduction

Due to ABET accreditation requirements and the increasing emphasis to include professional practice in the education program, most engineering departments are actively seeking industrial partners through setting up an industrial advisory board[1, 2]. However, in order to sustain the interaction and truly take advantage of the participation of industry leaders, many programs have developed various models suitable for their specific needs[3]. Most programs involve their councils beyond a simple advisory role such as curriculum, extracurricular activities, research, and faculty development[4, 5], some programs make use of industry-sponsored projects[6], while others suggested integrate practice-oriented education of engineers by working with industry partners[7].

In this paper, we present our experience in working with our industrial partners to integrate many of these activities in order to provide more professional practice skills beyond traditional engineering education to our students. We believe our recent success in fostering sustained industrial partnership is the direct result of the following practices:

- Proactive recruitment: selecting partners who have long-term interest to affiliate with the program and replacing inactive members through normal attrition.
- Relevant engagement: involving partners with activities that have potential impacts on the program and providing them with a well-planned agenda so they feel full engaged and take ownership of the affiliation.
- Steady leadership: selecting and retaining strong leaders who understand their roles by providing critical advice while staying away from academic policy interference. We have been fortunate to have both co-authors playing such roles.
- Synergetic activities: developing collaborations that are beneficial for all stakeholders such as lecture series, internship, hiring endorsement, etc..
- Innovation: exploring opportunities beyond traditional academic advisory function. For example, we have established international connections through some of our partners and use design projects and BS-MS sponsorships to broaden our industry partnership.

In the following section, we will discuss roles played by our industry liaisons through the advisory council followed by an overview of their involvement in the ABET assessment, sponsorship of senior capstone design curriculum, BS-MS dual degree program, and research collaboration. Finally, we used case studies and testimonials from two of our industry partners to illustrate how such a successful model can be fostered to achieve an academia-industry partnership that is sustainable and beneficial to all stakeholders involved.

Mechanical Engineering Advisory Council

Established in 1998, the Mechanical Engineering Advisory Council (MEAC) is a group of industrial, government, business, academic, and professional leaders who are interested in the vitality of the Mechanical Engineering Department (ME) and the College of Engineering (COE). The Council helps the ME and the COE strengthen its learning, research, and outreach programs, improve its facilities, expand its base of support, and serve its alumni. In addition, the council advises the ME on industry's perspective on engineering education, and helps with the sponsorship of senior capstone design projects and the implementation of dual-degree BS-MS and advanced degreed programs. Since its inception, the MEAC actively participates in the continual assessment of college progress and the development of college and industry partnerships. The inaugural MEAC was largely composed of distinguished, retired professionals who were replaced by general attrition. The MEAC was intentionally grown in size with a focus on recruiting more active members. In recent years, we are working hard to recruit a more diverse group of members which includes four African American and three female members. In addition, we have also added six of our alumni to the MEAC. Presently, the MEAC is composed of 18 outside members plus the Chair of the ME Department. The current MEAC is felt to be about the right size but recruitment remains an on-going effort due to periodic attrition.

Two of the industry co-authors joined MEAC in 2007 and 2008, respectively. Dr. Gregory Kostrzewsky also serves as the MEAC Chair since 2010, providing a steady leadership for the council since then. Both are among the most active members who are involved in curriculum assessment, senior design project sponsorship, and BS-MS internship & project sponsorship. Both industry co-authors also hold leadership positions in their respective companies and have the capability to make hiring and funding allocation decisions, which are critical to assist in the implementation of design project sponsorship and BS-MS internship recruitment. They have a similar background as they both hold doctoral degrees in engineering, have extensive research experience before joining industry, currently work in the manufacturing industry, and have responsibility in research and development for their companies. The other valuable attribute is their appreciation of the academic setting which is not surprising for Dr. Lin Xiang Sun since he previously served as an engineering faculty member. Dr. Kostrzewsky has also prior experience working with academia. It is fortunate we have involved them as industry liaisons for our program. They provide not only valuable feedback for the improvement of our curriculum but also resources and professional development opportunities for our students. Testimonials about their interactions with the program will be detailed later.

Senior Capstone Design Projects

The mechanical engineering capstone senior design course has gone through a progression of improvements since its transition to the current two-semester format in 1999[8]. Over the years, we have made steady improvements by working closely with MEAC and other external sponsors from industry and research institutions[9] by initiating international design projects working with institutions from Brazil and Romania[10] and by increasing multidisciplinary projects and design competition events collaborating with other engineering departments[11]. It is widely accepted that industry supported projects can provide great benefits in an academic design program since they often expose students to real-world challenges[12, 13]. These projects offer open-ended problems with the involvement of engineering professionals as mentors with the intention to foster a more industrial-like environment.

Mainly due to the active involvement of the MEAC, we have been successful in soliciting many long-term sponsors who provide high quality industry sponsored and engineering relevant projects. Every year we work with our industry partners to identify the projects by defining the expectations of the industry partners and discussing the relevancy of the projects as an appropriate learning experience for our students. Over the years, we have steadily increased our industry sponsored projects from a very few to the majority of the projects. About half of this current year's projects are sponsored by industry and we have a relatively high return rate from our industry sponsors[14]. For example, through the arrangement by Dr. Kostrzewsky, Cummins has sponsored a total of 20 projects since 2005 while Dr. Sun's corporation (Turbocor) has sponsored nine projects since 2008. MEAC members have consistently sponsored a significant number of projects in the past.

Annual Senior Design Open House

At the end of every school year, the ME department organizes a one-day project review event featuring final presentations and a design open house. All teams are required to make oral presentations followed by a poster session to showcase their projects and the design prototypes. We have also integrated the annual open house with our continuous assessment process to identify any strengths and weaknesses of the curriculum for modifications and improvements. This tightly interwoven relationship between the capstone course, curriculum evaluation, and MEAC participation has served the department well in many fronts: continuous improvement of the capstone course and curriculum, harvesting of relevant projects for the capstone course through strong industrial involvement, and expanded career opportunities for our graduates. Several curricular modifications are either directly or indirectly driven by MEAC feedback. As an example, as suggested by MEAC, a mechatronics curriculum was developed in light of the increasing important of smart system integration in both industrial settings and commercial products. As a result, we have substantially increased our mechatronics-relevant projects over the years while further enhancing our students' capability to work on multidisciplinary (MD) projects. The direct result is the expansion of MD projects in recent years working with three other engineering departments (17 MD projects in 2013-14 and 19 MD projects in 2014-15) with great than 50% of our projects being MD projects in recent years[14] as shown in the following two tables. The last column in Table 1 shows ME senior students who participate MD design projects as compared to the overall ME enrollment. As an example, 65 ME students work on 19 MD projects while the total enrollment of the class is 117 working on 31 projects. The total numbers of MD teams are also included in the parenthesis to show the growing trend from 5 in 2009-10 to 19 in 2014-15. Table 2 shows the ongoing MD projects with titles this school year and the composition of each team. We have also indicated those projects that contain significant mechatronics components. Readers can refer to the senior design web site to browse through the 300+ projects carried out by our students for the past 16 years:
http://eng.fsu.edu/me/senior_design/.

Table 1. Historical Development of MD projects in the COE

Academic Year	MD Project Students (Teams) in Each Dept.			
	CEE	ECE	IME	ME
2009-10	0	15 (5)	0	17/60 (5/19)
2010-11	0	18 (7)	9 (4)	25/58 (9/19)
2011-12	0	32 (11)	14 (5)	37/90 (13/27)
2012-13	3 (1)	24 (8)	0	24/81 (7/24)
2013-14	3 (1)	42 (16)	14 (7)	52/87 (17/27)
2014-15	2 (1)	32 (15)	9 (4)	65/117 (19/31)
TOTAL	8 (3)	163 (62)	46 (20)	220/493 (70)

Table 2. 2014-15 Cross-Departmental MD Projects

Project Description	CEE	ECE	IME	ME
ASME competition: Robots for Relief*		X		X
AUVSI design competition*		X		X
Educational kit using an Alkaline Membrane Fuel Cell		X		X
Weeding Robot*		X		
Solar Powered Wireless Infrared Monitoring System*		X		X
Prototype machine for Coating Stabilized lithium metal powders		X		X
Penetrometer Development*		X		X
ASME 3D Printing with Reinforced Ceramics		X		X
Underground Robotic Gopher Tortoise Scope*		X		X
Development functional Pedibus	X			X
Development of a Wheel Force/Torque Sensor for Autonomous Ground Vehicles*		X		X
Taller Wind Turbine for Low Wind Speed Regions			X	X
Solar Sausage for electricity and potable water supply systems		X	X	X
Electronic Synthetic Active Aperture Array Imager*		X	X	X
Efficient Systems' Electric Bike Sharing*		X		X

Project Description	CEE	ECE	IME	ME
SoutheastCon 2015 Hardware Competition*		X		X
Development of Palm Fruit Harvester		X	X	X
Design and Manufacture of a Rotorcraft*		X	X	X

*Indicated projects with substantial mechatronics design elements

BS-MS Degree Program

It is well known that industry needs people who not only have a sound education in mathematics, basic sciences, and engineering science, but who also have knowledge and experience in the solution of real world, product-driven problems[15, 16]. However, these increasing demands on the undergraduate engineering curriculum could not be satisfied within the parameters of a traditional four year undergraduate curriculum. The five-year BS-MS program is designed to satisfy the industry needs by coordinating the curriculum to combine four traditional undergraduate years with a fifth graduate year to receive stronger analytical training. The program also includes the integration of industrial experience through summer internships and mentoring of industry-sponsored product-oriented projects.

BS-MS students follow the normal undergraduate curriculum in ME through their third year while taking two graduate-level classes in addition to the normal BS course load in their fourth year. Immediately after receiving the BS degree, students are required to work in industry or government laboratories to gain practical work experience while earning academic credits towards their graduate degree during that summer. Upon returning from their summer internships, students complete a program including five regular graduate classes and a two-semester course sequence in which the students participate in practice-oriented externally sponsored design projects.

The summer internship requirement can be considered the starting point of a student's professional career with formal recruitment and interview processes and the engineering practice training in industry. During summer, students are also required to engage their job supervisors to develop the practice-oriented design projects which they can work on after returning to school. This added responsibility thrusts students to be more resourceful beyond routine summer intern assignment since they need to employ effective communication skills, salesmanship and organization to achieve this. The tasks also include the solicitation of partial funding of projects so that sponsors are obligated to provide sustained mentorship to students when they work on the projects during the fifth year. This engagement fosters long-term cooperation between industry or government agencies and the ME, which is vital to the success of the BS-MS program. Since 2005, we have worked with 17 companies and five research laboratories/government agencies in sponsoring 56 BS-MS projects. Overall, the BS-MS program is very successful as it expands our industry partnership by actively involving them in our professional preparation program while broadening employment opportunities for our graduates. Statistically, about 30% (15 out of 49) of BS-MS program graduates eventually work for the companies sponsored their projects.

Being a relatively young engineering program without a strong, local industry presence, our program has tried hard to increase industrial partnership through a step-by-step approach through MEAC, senior capstone design project sponsorship and the BS-MS program. We consider the model to be reasonably successful considering many constraints imposed including factors such as limited resources, lack of a local industry base, an under-developed alumni base, etc.. The active participation of MEAC is the most critical component leading to any success we might have. Among those involved, two members truly stand out due to their passion toward engineering education, an understanding of the importance of academia-industry partnership and the willingness to contribute time and resources. In the following, Dr. Kostrzewsky and Dr. Sun will elaborate on their respective experiences as case studies about the sustained development of their affiliation with our program.

Case Study 1

Cummins is a $17 billion Fortune 200 corporation comprised of complementary business units that design, manufacture, distribute and service diesel and natural gas engines and related technologies, including fuel systems, controls, air handling, filtration, emission solutions and electrical power generation systems. Approximately 48,000 people are employed worldwide, more than half of whom work outside the U.S., resulting in a very diverse workforce. A large number of these people are employed in engineering roles including design, research, new product development, current product support, plant product engineering, reliability engineering, service, and manufacturing.

Due to growth as well as attrition, the company's continued success hinges on recruiting top technical talent. One way this is achieved is via collaboration with engineering colleges. The company established and maintains close relationships with selected institutions in the U.S. as well as England, India, and China. In this instance, a relationship was established with the example university over 10 years ago primarily based on its success in educating African American Engineering students. At the time, the university was ranked among the top five in the U.S. in this metric[17]. Focused recruitment efforts at the example university grew to include Hispanic and women engineers.

Senior design projects allow students to apply their skills and experience to undertake meaningful engineering design challenges in a team setting similar to that found in industry. The capstone course provides a realistic industrial structure and mimics professional expectations for the design project activities and results. The company sponsors several teams each year, providing financial support, design project ideas, as well as project mentors. The involvement is also a path through which the company can influence non-technical expectations and help develop student's skills in areas including leadership, teamwork, and project management. Project involvement and participation in senior design project reviews give the company an advantage in identifying those students who demonstrate the "soft" skills well and are highly capable and motivated. Since 2005, the company has sponsored 20 projects with two current projects in 2014-15. These projects include a wide range of topics such as product development, energy usage audit, materials characterization, among others.

One or two senior design projects per year are international in nature. An exchange program between the example university and a university in Brazil has been active for several years. Project teams are staffed with students from both universities. Students learn skills valuable in the modern work environment by working collaboratively across continents, cultures, time zones, and language barriers. The global nature of the company also supports exploration of international programs by presenting internship opportunities at the company's engineering center in Brazil. In addition, the academic author has visited the company's design center in China and initiated discussion to develop similar collaborative activities there.

Through Dr. Kostrewsky and his co-workers, Cummins also participates in the dual-degree combined BS-MS program and, on average, more than one student per year is selected by the company for sponsorship (a total of 13 students since 2005). As described earlier, the student receives an internship during the summer after their senior year, and then returns to school to complete a BS-MS project and coursework. The BS-MS project is related to the work the student performs during the internship. Execution of the project builds relevant experience for the student and completion of the project addresses an initiative or technical gap for the company. The success rate in terms of recruiting and retention is very high; the student usually ends up working for the company when they have finished their studies (for instance, 7 BS-MS alumni eventually worked for Cummins over the past 10 years).

Cummins finds that active participation in an advisory council helps the university improve, supports ABET accreditation via industry partner assessments, and yields closer access to recruit top graduates who would be successful in the company's diverse work environment.

Case Study 2

Danfoss Turbocor Compressor is a manufacturing company belonging to a global cooperation with over $6 billion sales and 24,000 employees globally. The sales and number of employees in North America represent 23% and 17% respectively of the global totals. The business unit operated locally in a nearby industry park is recognized as the pioneer and world leader of the oil-free centrifugal compressor product category. The enterprise is dedicated to the design, manufacture, marketing and support of the world's most efficient commercial refrigerant compressors by developing the world's first totally oil-free compressor for the HVAC industry. The company employs about 200 people as part of the Climate and Energy Division of a global company but operates as an independent business. The company has been recognized with many awards from a number of prestigious organizations and the continued development of state-of-the-art technology is critical to maintain its leadership position in the competitive field of commercial HVAC applications. Due to its proximity and technology-based business model, it is logical for the company to get involved with the engineering program. The connection was initiated immediately after its relocation in 2007. However, one critical factor for the sustained partnership is due to the commitment of the company's technology leader, Dr. Sun, who was an engineering faculty and who believes that it is mutually beneficial to have a strong academia-industry collaborative program.

Starting with Dr. Sun, several people from Turbocor's leadership team got involved with the school serving in advisory councils at university, college and department-levels. While serving as a MEAC member, Dr. Sun began to sponsor senior design projects immediately after the relocation. Since 2007 until this year, the company has sponsored a total of nine projects. In contrast with Cummins, students can interact directly with engineers and technicians of Turbocor due to its proximity to the college. During the semester, project students can visit the manufacturing shop, conduct face-to-face discussions with mentors, and take advantage of the industry-scale machining capabilities and procurement process. These students essentially serve as Co-op students during the project implementation phase and receive first-hand industrial product-development experience. From the company's perspective, the students can use the senior capstone design project opportunity to explore non-critical engineering operations and/or long-term aspirations. The close and persistent interaction also allows the company to observe students' skills, motivations and attributes to identify potential candidates for employment.

Turbocor also participates in the BS-MS program by sponsoring students through summer internship as well as year-long BS-MS project mentoring. Four students have been recruited since 2010 and one more is expected to work in the coming summer. Among those students, two had already been hired by company Y and both have served as liaisons to continue the partnership. Turbocor's past commercial success was built on the advancement of leading-edge technology. Thus sustained research and development is critical for its future growth. Arranged by Turbocor, Shih, along with one colleague, has travelled to Danfoss Inc.'s Danish headquarters and its German subsidiary research center to develop potential research collaborations. As a result, a graduate fellowship sponsored by Danfoss Turbocor is established for one engineering student. Recently, her research work using the advanced flow control methodology has shown promising results for the performance improvement of Turbocor's compressors. We believe the joint research activity is a win-win situation for both partners because Turbocor can leverage the research infrastructure and faculty expertise provided by the engineering program while the students can be immersed in a real-world industrial setting working side by side with technology practitioners. Through the connection, several of the company's senior leaders also serve on advisory boards of the example university beyond the departmental level.

Summary

Engineering programs need to develop connections with industrial practitioners in order to receive relevant and up-to-date real-world feedback to improve their curriculum and professional preparation programs. The involvement of advisory councils comprising of active industry leaders is critical to cultivate such a strong affiliation. To foster a sustained partnership, the program methodically recruits active council members and engages them in activities leading to outcomes of mutual benefits for all stakeholders. We feel a steady leadership guiding the council is the most critical element for success. We also do not hesitate to develop innovative collaborations going beyond the traditional defined roles for the council. In this paper, we discuss our successful experiences working with an advisory council on curriculum review, continuous assessment for improvements, senior design project sponsorship and a BS-MS dual-degree program. In particular, case studies of how such a partnership could be promoted are presented by two council members representing their respective companies.

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