Academic and Industry Collaboration – A Literature Review

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Abstract

As part of a larger project determining best practices for establishing and maintaining effective, sustainable, collaborative relationships between academic and industry professionals, this review will outline the available materials and, conversely, the multiple gaps that exist regarding course content, methods of teaching, and practical experience relating to preparation for careers in engineering and engineering technology. Currently, there is no clear agreement on which principles and practices best enable industrial partners and academic institutions to establish and maintain mutually beneficial partnerships. In fact, there is no clear definition in the literature of what a mutually beneficial partnership entails, across the full range of educational, research, and professional development and service activities carried out within the engineering and technical community. The authors of this paper established informally that educators in both engineering and engineering technology are often challenged by this lack of research on sound recommendations regarding collaborative efforts. This paper is intended to be the start of a larger systemic literature review.

1. Introduction

To date, no broad, holistic studies have been conducted on best practices for maintaining multi-faceted relationships between industry and academia. There has been some research on collaboration between industry and academia, but it is far from complete, and usually focuses on the software and computing industries. There have been some studies centered specifically on research collaborations, but many of them were conducted outside of the United States, and therefore are limited in applicability due to differing cultures, academic structures, and government and regulatory environments. Some studies examined industrial involvement in capstone projects, but these studies focused primarily on what was being done in the classroom and its immediate impact on students. In our literature search, we have instead focused on several different areas that are relevant to this study: research partnerships, curricular partnerships, and other interactions between industry professionals and academics. This search expands on our prior work on industry-academia collaboration [1], which summarized various types of collaborations and examined their origins. Some of these collaborations were sponsored by governments, while others grew more organically as individual companies and universities established relationships. Those sponsored or facilitated by governments were, naturally, strongly impacted by the country in which they arose, as different countries had different perspectives on the role of government in the economy, society, and academia. As previously stated, however, many existing studies of these collaborations focus on different purposes of the relationship between industry and academia [1]. Some of these purposes include research partnerships, industry advisory boards, and various efforts to provide students with authentic engineering experiences (e.g., sponsored capstone projects, co-op programs, and internships).

With the knowledge that research on a variety of aspects has taken place, this concentrated literature review aimed instead to focus on areas critical to these authors. Of particular interest were research partnerships and those relationships where industry provides input into curricular partnerships, especially relationships centered around engineering and engineering technology programs. A final section of this brief review will outline areas that may benefit from further research that were found while searching for existing studies on this area of focus.

2. Research Partnerships

The importance of research involving industry-academia collaboration was recognized as early as the late 1990s, especially in software and computer science [2]. Professionals in both industry and academia realized that they had to cooperate to solve issues inherent to their work environments. Studies continue to focus on the computing field [3], which is linked to a higher employment rate of students from those fields upon graduation. Although the issues confronting industry and academia in longer-lived programs such as mechanical and electrical engineering are similar to those encountered in computing, most academic personnel lack extensive experience in industry and are less familiar with what industry needs in a recent graduate. This difference in experience has hindered the general awareness that further research in this area is necessary to aid students in making a smooth transition into industry following four or more years in an academic setting.

Some research does exist on the process of that transition, as experienced by students. Baytiyeh and Naja [4] identified "communication, responsibility, and self-confidence" as key challenges facing recent graduates, skills which the graduates themselves suggested would have been better developed by increasing collaboration between schools and firms. Additionally, the high value of industry placement for students who completed thesis projects was further established by Kovalchuk et al. [5], who noted that previous professional experience directly correlated with employability, and thus that merely increasing the availability and emphasizing the importance of experiential learning was a key part of equipping students to be part of the workforce after graduation.

Wohlin et al. [6] lend some insight on which factors make an industry-academia relationship more likely to be successful, identifying support from company management and an emphasis on on-site collaboration with a champion representative as some of the most important contributors. These factors are corroborated by Garousi, Petersen, and Ozkan [7], who include ensuring management engagement and the presence of a champion in the list of best practices most commonly recommended by members of these projects. The energy industry is becoming one such example of industry leading industry-academia relationships, in part due to a large percentage of the workforce, especially within that the utility and electricity sectors, nearing retirement age [8]. This situation has led many energy companies to seek out ways to attract and prepare students to fill this need for talent [8]. As such, industry itself becomes one of the most powerful influences for enabling partnerships with academia. By making opportunities for experiential learning more readily available to students prior to their entry into the workforce, companies may thus better equip future employees with the skills and experiences needed to succeed after graduation.

Curricular Partnerships

The inclusion of experiential elements into engineering curriculums has long been a focus of research, but it is only in the last decade that programs including these components have been developed [9] and their effects on students researched to any extent [10], [11]. These experiences take a number of different forms but may be categorized into three broad classifications: capstone [12], co-op [13], and internship programs [14]. Much of the available research in this area is focused on computer software and development programs, necessitating further research on curricular partnerships between other areas of engineering and engineering technology.

While most recent studies combine engineering technology students with engineering students in general or ignore engineering technology students altogether, researchers have found slight differences in these student populations [15]-[18]. Historically, engineering technology students have been taught using more hands-on pedagogy, with a greater emphasis on practical learning experiences [19], while the engineering curriculum evolved from a theoretical pedagogy based in a learning environment that did not place as high of a priority on experiential learning. However, recently, this has changed: programs in both engineering and engineering technology have begun to spotlight experiential learning. In fact, accreditation bodies such as ABET [20], [21] have recommended an experiential component as part of all bachelor's and even, if appropriate, associate degrees in both engineering and engineering technology.

The changing curriculum, the corresponding update of ABET criteria, and the redevelopment and adjustment of pedagogy thus motivate this research, as making experiential learning opportunities more available requires someone to provide the experience. Strong collaborations in the computing field between industry and academia have resulted in significant strides in student educational quality, including an improved ability to bridge graduation and begin a successful career. Existing research does suggest that more industry involvement in curricular development is needed, as there is still a gap [22] between what industry expects [23] and what recent graduates are perceived to deliver [24]. For example, the manufacturing sector has seen recent changes in the form of digital upgrades and the addition of artificial intelligence to advanced manufacturing requiring students to now be more tech-savvy to succeed in this field [25]. Increased involvement from industry, in this case and many others, would ultimately be beneficial both for meeting curricular recommendations and for appropriately equipping graduates to enter the workforce.

Furthermore, evidence suggests that senior management engagement within a business is one of the main drivers of industry-academia collaboration in curriculum design [26], [27], suggesting that industry itself is most poised to effect the changes it requires. Personnel in engineering and engineering technology recognizing differences in their approaches, however slight, collaborating with industry to appropriately modify their curricula, and developing and maintaining relationships to continue this collaboration would likely result in similar outcomes within their respective fields as those seen in computing.

Before that can be done, though, a more complete understanding of what students in these fields need and how those needs should be addressed is required. There are several unique challenges in applying the information derived from industrial collaborations in academic curricula. Desha et al. [28] assert that there is a "time lag dilemma," wherein the standard process of assimilating new regulations and guidelines into the educational process takes far too long for the resulting curriculum to be effective. Certain partnerships between industry and academia have also caused the development of narrowly-focused qualifications concentrated only on one engineering field, which limits the ability of students to transfer skills between different industries and makes such programs unattractive to higher-achieving graduates, despite the increased availability of work placements and funding for lecturers for the university [29], although there are solutions available for some of these issues. Desha et al. [28], for instance, describe a "rapid curriculum renewal" approach to assist educators in addressing their risk exposure to likely shifts in industry), not all of them are so easy to resolve.

3. Other Interactions

The synergy of academia and industry has two basic components. The first is the formal component, which is comprised of interactions in academic settings, such as capstone projects, or internships and co-op experiences. The other is the informal component, and literature documenting these relationships and interactions is difficult to find. The researchers have contemplated these issues for some time, and through previous work, found that professional societies provide some means for academics and industry professionals to interact in an informal setting [1], [30].

With this interaction in mind, there are a few more issues to consider, first and foremost being the likelihood of academics to be a member of a professional society in the first place. Based on prior research currently in review, academics in engineering technology tend to have a large amount of industry experience and potential for professional society membership and continued interaction with their peers. Further work in this area focuses on students and their affiliations with professional societies [31] and the subsequent effect of that affiliation on their identity within the engineering community.

Ansmann et al. [32] mention that membership in a professional society is a powerful form of networking, which was found to be one of the most robust predictors of both actual and perceived career success. Furthermore, as was found by Godwin and Lee [33], perceived success and competence are themselves correlated with the strength of a student's identification as an engineer. This implies that the greater the opportunity for students to join a professional society and the greater amount of informal peer interaction between industry and academia, the more likely that those students will be able to identify as an engineer throughout the course of their education and thus to establish a successful career in the field later on.

Such informal approaches to helping students better prepare for industry, however, may not necessarily arise only in the form of networking at the professional level. One unique method involves a summer school program that students may sign up for in lieu of an internship [34], which arose as part of a Chinese university-industry-government collaboration that sought to address concerns that opportunities for students to keep up with new technologies were lacking [34]. The program aimed to provide students with the latest industry technical training and the opportunity to work on actual industry engineering projects [34]; such initiatives would not only allow students to stay on top of changing technological trends in industry, but also to apply these technologies to actual engineering projects as a valuable experiential learning option.

4. Discussion

Tonso [35] shares that learners who do not identify with engineering eventually move out of the engineering field. Seymour & Hewett [36] assert that identity and learning are interconnected, supporting Tonso's conclusion that, as an individual transforms from novice to experienced, they move from being peripherally involved in a discipline to identifying with that community. Ultimately, over time, the individual identifies with the area in which they work, and therefore students approaching the end of their studies are generally more able to identify as an engineer, defined as someone who is competent in a field requiring functional knowledge of technical concepts [37-39].

The importance of being part of the community and the interaction between academics and industrial professionals on that feeling of identity throughout a student's studies cannot be stressed enough. Research shows that engineering technology students were generally left out of the engineering community until the last ten years. In that time, however, they have assimilated into the community, enabling more of them to take on positions with "engineer" in the title and to take on more responsibility than they were historically given [40], [41]. Thus, in order to enable more students to better fulfill the needs of industry post-graduation, it is crucial for them to be allowed to identify as engineers throughout their education and careers, whether through informal extracurricular interactions as described previously, or through curricular design.

However, a large amount of the responsibility for enabling these pathways in the first place falls on industry rather than academia. Experiential learning is critical in adequately preparing students for the workforce later on, but many of the factors that enable the successful relationships that make those opportunities available fall on the industrial, rather than the academic, side. This holds true in terms of both research partnerships and curricular design, especially in the sense that strong engagement and initiative from industry is often correlated with successful industry-academia relationships.

Ultimately, industry cannot expect academia to produce the ideal workforce without a significant amount of collaboration. Although the attitude and initiative of academic representatives is key [42], it is also the primary responsibility of management in the industrial setting to dedicate the resources and engagement required to nurture existing industry-academia relationships, allowing both parties to derive maximal benefit from those interactions. Communication is key; without a clear idea of what industry requires from graduates entering the workforce, no amount of curriculum restructuring, or pedagogical change will adequately prepare students for the transition out of academia. As the importance of experiential learning continues to rise, the importance of establishing these relationships will rise with it.

5. Potential for Future Work

This review has provided a clear understanding that organizations such as ABET and professional societies find capstone and similar end-of-program projects that encourage synthesis of student knowledge to be beneficial. However, research on the varying formats of these end-of-program projects or even intermediary techniques and the effects of that variance on the ultimate benefit conferred by the project is lacking. Future research would benefit from a deeper comprehension of what a student gains through group work, as well as understanding those students that express frustration with such learning environments.

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