Addressing Business Research Needs in the Engineering Curriculum

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Abstract

Teaching business competencies in the engineering curriculum frequently happens in support of entrepreneurship and/or management and leadership programs. However, in the College of Engineering at Cornell University, business and engineering also intersect in a more ubiquitous manner, including traditional coursework and co-curricular initiatives. Examples of this include projects where there are corporate partners, business and leadership skill development in student project teams, market and consumer aspects of design courses, and training focused on organizational communication. To address these real-world applications of engineering, and the external factors impacting theoretical approaches, students need to research companies, industries, business environments, organizational behavior, and sources of financing.

This has prompted the Engineering Library, part of the Cornell University Library system, to think about approaches for supporting business research, in addition to the all-important design, build, and modeling work of engineering and science. Increasing the number of collaborations between business and engineering librarians to provide research assistance and instruction has been one approach and cross-training on databases and subject expertise is another. Finally, adopting different pedagogical styles and considering disciplinary contexts and language has been essential.

This paper will provide short case studies where business and engineering intersect in the College of Engineering at Cornell University that also detail our approaches. Furthermore, it will discuss the outcomes of our efforts and the successes and challenges encountered as we work to address business research needs in the engineering curriculum.

Introduction and Literature Review

The teaching of business competencies to engineering students is exploding in engineering education due to a variety of factors. First, there is a critical need to develop professional skills, including leadership, communication and teamwork, and capabilities for “real-world” engineering design and operations, along with learning the core math, science, and technical aspects of engineering [1], [2]. Interviews and surveys of early-career engineers revealed not only technical skills were needed but also skills for industry, like complex project management and soft skills, that newcomers had to learn or were identified as important [3]–[6].

Another factor is booming activity around entrepreneurship as engineers become an essential part of that ecosystem because of their ability to design and create materials, systems, and technology. Recognizing this impact, the U.S. Economic Development Administration (EDA) has announced funding opportunities, including its STEM Talent Challenge [7] and its

University Centers program [8], to boost the innovation economy across the nation. Similar efforts by the National Science Foundation (NSF) supported introducing entrepreneurship education in many institutions' engineering curriculum and creating co-curricular or extracurricular programs [9]–[12]. Thus far, industry experts who have participated in such entrepreneurship education expressed positive feedback to the value of the programs for providing engineering students with professional skills and an entrepreneurial mindset [6], [13].

Entrepreneurial activity in engineering has even prompted some to suggest a change to ABET (Accreditation Board of Engineering and Technology), the organization which oversees accreditation of engineering schools, outcomes to further develop business and entrepreneurship skills. In their article, Sababha et al. [2] wanted to add the following ABET learning outcome: "to develop and evaluate a business plan that transforms an engineering design (system, products, services, and solutions) into a business opportunity utilizing entrepreneurial skills and knowledge" [2, p. 2]. They go on to state that this can be supported by the growing number of entrepreneurial courses which have been added to the curriculum, by having students working on projects with companies, and by working with the technology transfer office within the university [2, p. 3].

The last factor driving business representation in engineering curriculums is an increase in the number of interdisciplinary programs on campus. Formal intersections that occur within existing curricular frameworks, and include some form of collaboration, were illustrated in multiple studies. Those include integration of case-based learning or business skills training to an engineering course sequence [6], [14], [15], transformation of a traditional engineering curriculum by incorporating and reviewing societies policies and framework, including ABET program outcomes and the KEEN Framework on the Entrepreneurial Mindset [10], and establishment of new engineering education and leadership degree programs [16]. In a rather informal way, experiential learning programs were created or piloted as co-curricular or extracurricular programs in others [9], [17].

There are limited articles in the literature for how libraries and librarians are addressing business research needs in the evolving engineering curriculum or the general intersection between business and engineering in academic libraries. Previous studies emphasized the importance of collaboration, specifically on the intersection of engineering and business librarians, in supporting interdisciplinary research, innovation and entrepreneurship in higher education [18]–[21]. Collaboration and close partnership between the two liaison librarians resulted in improved collection development practices, promotion of new instruction opportunities, and the ability to substitute teach in each other's liaison areas when needed [19]. Similarly, MacDonald [22] presented a case study of such collaboration more narrowly focused on the intersection of chemistry and business, rather than innovation and entrepreneurship more broadly, for supporting career search and development. Another case study described a critical librarianship

approach by business librarians to teaching patent searching to students in business and finance fields [23].

This paper will add to the academic library literature by providing short case studies that outline how business research skills are being taught to engineers by business and engineering librarians at our institution.

Institutional Context

Our private and land grant institution has a total FTE of 25,582 [24] with eleven colleges and schools that operate across two campuses. The College of Engineering's mission is to "provide students with a broad and exceptional education that prepares them to excel in traditional and non-traditional aspects of engineering." [25, p. 3], and includes 14 departments and schools ranging from biomedical to civil to operations research and information engineering. There are robust undergraduate and graduate programs, with fall 2022 undergraduate enrollment at 3,287 and graduate enrollment at 2,409 [24]. The College is an integral part of the larger campus entrepreneurship ecosystem, and there has been a sizable investment of space for undergraduates, graduate students, and faculty.

The physical Engineering Library has been in its current location since 1957 and is a dynamic, service-oriented, and user-centered space that partners with the College of Engineering and College of Computing and Information Science to support their teaching, research, learning, and experiential missions, and the broader mission of our institution. The library provides collections, services, space, and staff expertise. Since 2019, the engineering librarians have been organizationally aligned with the business libraries and librarians on campus to create a department focused on business, engineering, and entrepreneurship (BEE). This has resulted in increased opportunities for collaboration, co-training, and innovative ways to support the cross-disciplinary needs of our patrons.

Case Studies

This section of the paper provides engineering-focused courses and a program where librarians in the BEE department addressed business research skills. Table 1 shows an overview of the cases, including the course title, level of students, learning outcome/objective, and specific business research skills addressed.

Invention and Technology Commercialization: IP Management for Scientists, Engineers, and Entrepreneurs (GDEV 4050)

Invention and Commercialization is a course in the Department of Global Development, College of Agriculture and Life Sciences at Cornell University, which includes the Department of Biological and Environmental Engineering. It is part of eCornell, an online suite of courses open

Table 1. At-a-glance summary of the five case studies.

Course	Level of Students	Program Learning Outcome/Objective	Business Research Skills Addressed
Invention and Technology Commercialization	Seniors, graduate students & alumni	Understanding and management of all forms of intellectual property. Effective patent and literature searching.	● Patent licensing and commercialization ● Market research
Chemical Process Design	Seniors	Design all aspects of a chemical plant including technical design, processes, and operating costs.	● Locating production, consumption, and pricing data ● Industry research
Applied Operations Research and Information Engineering and IT Projects	Graduate students	Design, analysis, and evaluation of solutions to real-world, applied problems in operations research and information engineering with company partners.	● Company research (SWOT analysis, news, and corporate strategy) ● Industry and market research
Physical Design in Biological Engineering	Undergraduate students & graduate students	Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as relevant global, cultural, social, environmental, and economic factors.	● Researching the larger context and problem driving design. ● Market and consumer research ● Product landscape
Engineering Student Project Teams	Undergraduate students	Understand the complete design and build cycle of a product, system, or service.	● Company research for potential sponsors/partners based on criteria ● Industry research

to the public for a fee. Learning outcomes include being knowledgeable about literature searching, searching prior art for patents, seeking patent protection, and licensing or commercializing their invention and technology. Library instructors needed to discuss freely available information, since some of these students may not have access to subscription databases and journals. The Lens and Google Patents were demonstrated. The same course is

taught during the regular semester in the Department of Global Development, and for that the librarian has to pivot to cover subscription databases.

Librarian involvement included several meetings with the instructors and deliverables included creating a LibGuide, a downloadable *Best Practices for a Prior Art Search* document, and short answers to six questions as part of their *Ask the Expert* video series. These answers were video recorded and presented to the students to watch asynchronously. Powerpoint slides or database screenshots were not used as the focus was on the interviewee, which was refreshingly different from what the librarian was used to. Besides describing tips on searching patent databases, including filtering and classification searching, the librarian discussed business information to help students gauge the commercial potential for a patent. The engineering librarian consulted with the business librarians to glean the best answers for this, and the business resources mentioned included freely-available government and trade associations statistics and publications, including demographic data, and the "investor relations" sections of public company websites for product information and statistics.

Chemical Process Design (CHEME 4620)

Of all the examples of collaborative instruction between engineering and business librarians at Cornell University Library, *CHEME 4620: Chemical Process Design* is the longest-running. Chemical engineering undergraduate students are required to participate in a yearlong capstone project; *CHEME 4620* is one of two design courses students can choose to satisfy this requirement. In the class, students are tasked to design chemical plants through challenges posed by corporate partners spanning the petrochemical, pharmaceutical, and consumer product industries. Due to the longevity of this successful collaboration, many librarians have supported the course throughout staffing changes. Engineering librarians introduce research strategies for locating and using safety regulations, process design documents, chemical data sheets, formulation handbooks, and patents. Business librarians demonstrate how to find commodity and bulk feedstock pricing and perform market and industry research.

When introducing search techniques for locating chemical prices to engineering students, business librarians have learned to adapt their approach in order to make student researchers aware of the volatility of commodity trading prices. While the engineering curriculum emphasizes the precision and accuracy of design calculations, business students learn to embrace the "squishy," or approximate, nature of pricing and project estimates. To help students acclimate to this concept during the instruction session, business librarians contrast the consistency of the number of atoms in a chemical molecule to the inconsistency of the price of a gallon of milk, a shopping experience that students are more familiar with in their everyday life. The cost of a gallon of milk can change over time or based on where or the quantity in which it is purchased, which is also true of the chemicals needed for project processes. For these reasons, students cannot expect that they will arrive at a single "correct" estimate of a price the way they would

arrive at a correct ratio when researching chemical composition. One-on-one follow-up research consultations are often required, since there is no single source for pricing data and students may need to consult a variety of resources, including databases like Bloomberg and Scifinder and periodicals like *ICIS Chemical Business*. Librarians have also found that they need to reinforce the concept of "squishy" pricing in research consultations as students become frustrated with the lack of available data online.

Applied Operations Research and Information Engineering and IT Projects (ORIE 5980)

Librarian support of *ORIE 5980: Applied Operations Research and Information Engineering and IT Projects* began in the 2022-23 academic year after the course instructors were introduced to the engineering librarian at a departmental event. The course, a requirement of the Operations Research and Information Engineering (ORIE) master's degree program, is the first of a two-part yearlong sequence addressing a project challenge posed by industry partners. Based on their own experience working in the field, the course instructors felt that their students could benefit professionally by learning to present their projects as they relate to their employer's business goals, rather than in a strict engineering context. For this reason, they hoped that their students could learn to assess the company and industry conditions impacting their assigned projects.

Before the instruction session, the engineering and business librarians met with the instructors to discuss students' research needs. Upon request, the instructors also shared the list of project prompts. This often requires the approval of partner firms, who may prefer to limit disclosure with outside parties for competitive reasons, so it is important to communicate early to secure the information in a timely manner. Relatedly, librarians should expect that they may need to sign a non-disclosure agreement (NDA) if they are requesting project details. The business and engineering librarians worked together to build a course LibGuide with research strategies for locating engineering papers and e-books along with company and industry information. During instruction, the engineering librarian demonstrated databases related to engineering information and citation metrics such as Engineering Village, Knovel, and Scopus. She also demonstrated citation management using Zotero. The business librarian demonstrated how students can better understand their partners' business strategies by consulting corporate websites, industry reports from IBISWorld, and SWOT analyses from MarketLine. The librarian used assigned corporate partners as example companies for her live demonstration, illustrating for students the relevance of business research to their design projects. In class, students were delighted to see their own corporate partners highlighted, and the instructors also provided positive feedback about this approach. It was clear that the additional work of requesting company authorization to share the project prompts was a worthwhile pursuit. The instructors also pointed out that the librarians' involvement in the course resulted from a networking interaction and encouraged students to embrace professional networking to benefit their careers. As the library's association with this course is new and student research continues into the present, this partnership will continue to evolve.

Physical Design in Biological Engineering (BEE 4590/ENGRC 4950)

The Engineering Communications Program in the College of Engineering helps undergraduate students become efficient and effective communicators. They teach courses to address the Engineering Communications Requirement in the curriculum and also focus on developing integrated teaching partnerships with disciplinary faculty across the college. It was through one of these teaching partnerships with a Biological and Environmental Engineering course that an embedded librarian/instruction opportunity arose that resulted in the teaching of business and general research skills, including defining a problem, market and consumer research, company information, patent searching, and data. General information literacy skills addressed were source evaluation, synthesis and use, and written and oral citation.

The Engineering Library at Cornell University was asked to partner in the engineering communications component of *BEE 4590: Physical Design in Biological Engineering* to support its outcomes and the course overall. Librarian involvement included creating research-based learning outcomes, providing feedback on assignment structure and assessment rubrics, creating and delivering lectures on research components and skills, attending class weekly, conducting research consultations to address specific team needs, and grading both the draft and final presentations with a rubric that included a metric for evidence and research. While the engineering students enrolled in the course were very skilled in design, technology, and engineering, they had less experience with both communication and secondary/library research. No formal assessment of research or information literacy skills was conducted; however, anecdotal assessment and observation revealed that the students were most comfortable when engaging with freely available websites, lab-generated data, some scholarly journal literature, and technical information. It should be noted that while the course enrollment consisted of undergraduates, individual skill sets and experiences were varied, and that had an impact on their comfort with information engagement and use. For example, two students in the class were in the process of applying to graduate school, and therefore, had more experience with scholarly journal literature.

As stated above, there were several business research needs addressed in the course, however, we will only detail one aspect here, which was to help the students identify and define a target consumer. It was important for them to do this because they needed to ensure their design was something people would eventually buy. Additionally, the identified consumer could impact certain features of the design itself. In addition, their final presentation needed to represent this information as part of their background investigation.

To address this research need, the librarian first provided some definition and background on target consumers and instruction on the types of information one can use to develop an understanding of them (i.e., demographics, psychographics, buying preferences, etc.). It was also noted that the target consumer, in some cases, might be an organization or institution. Students

were then asked to engage in an activity in which they developed a persona for their target consumer without doing any research but based on their own understanding, ideas, and imagination. Next, the librarian demonstrated and explained both subscription databases such as Mintel Academic, Frost & Sullivan, and SimplyAnalytics that provide market research and consumer information. There was also a brief discussion about conducting primary research to help define consumers, particularly when addressing a niche design that is not represented in existing information sources. Then students used these resources to provide evidence to support their created persona, or to develop a new one if their research revealed information that diverged from the original ideas.

Engineering Student Project Teams

Cornell University's *Engineering Student Project Teams* is a co-curricular program that offers experiential learning opportunities. They are entirely led and managed by undergraduate students, which allows them to gain valuable real-world engineering experience through the complete design and build cycle of a product, system, or service. Currently, the program consists of 34 teams and approximately 1,400 students from various colleges on campus, including the College of Engineering, College of Business, College of Architecture, Art, and Planning, among others.

Each student project team includes a business subteam responsible for finding corporate partners for monetary support. To this end, they work closely with the Alumni Affairs and Development (AAD) office at Cornell University, where expert officers provide guidance on best practices for communicating with potential corporate sponsors. However, the teams are expected to conduct their own research to find corporations in their specific field. To address this, the program's professional staff hosted an introductory workshop for business subteam leaders, where an engineering librarian and AAD officers were invited to introduce useful resources, tools and guidance for finding and communicating with potential corporate partners.

To prepare for the workshop presentation, the engineering librarian reached out to business librarians to receive cross-training on relevant business databases like Capital IQ. Since there were previous cross-training efforts, it didn't take long for the librarian to know whom to contact and to update her knowledge from previous training. At the workshop, the engineering librarian delivered an up-to-date introduction to library resources for identifying potential corporate partners, including sophisticated company screening tools, that meet specific criteria such as company size, primary industry, and education (i.e., Cornell alumni). The staff of the program added that such curated library resources for business research will be helpful in pre-screening a large number of companies in initial stages.

Librarian support for the student project teams is not only limited to business research. In previous years, student project teams researched safety documents, such as fire codes and safety standards, on their own. For years, the Formula SAE team has used the Society of Automotive

Engineers (SAE) papers and standards, some of which the library orders on demand. To assist with such needs, engineering librarians can provide additional support to the teams, particularly with demonstrating reliable and domain-specific resources for more efficient searches. The engineering librarian aims to continue to offer introductory workshops and deliver up-to-date information on business and engineering research to the student project teams in close collaboration with the business librarians.

Conclusion

Several conditions have contributed to escalating demand for business education in the engineering curriculum: the heightened emphasis on building professional skills in response to industry expectations, the increase in funding for entrepreneurial projects on college campuses, and the growing number of explicit business-engineering curricular intersections manifested in interdisciplinary programs.

In response to this increased demand, Cornell librarians have adapted their business research support to a new audience of engineering students. The case studies above serve as examples of our efforts and detail the successes and challenges encountered throughout our work.

Project-based learning is increasingly common in the engineering curriculum; these courses represent low-hanging fruit for cross-disciplinary library instruction, so consider targeting them first. Teaching directly to the project prompts links your teaching demonstrations to the students' information needs concretely, complementing the applied nature of project-based learning. When providing library instruction for projects with corporate partners, we recommend requesting project prompts ahead of time, with the expectation that you may be asked to sign a non-disclosure agreement.

When possible, we recommend cross-training or co-teaching to fully capitalize on engineering librarians' familiarity with the departments, faculty, and students they work with most closely. Engineering librarians should identify and share potential pain points, like students' aversion to "squishy" numbers, that warrant additional attention during lesson planning. Co-teaching sessions also model the cross-functional work that engineering students can expect in their future careers.

An increased emphasis on communication with both faculty and students also supports improved student learning. Conversations with faculty about their expectations are essential when engaging in cross-curricular instruction since terminology and expectations can vary. Finally, expect that follow-up research consultations or reference emails may be necessary as students build new skills. Overall, we have been pleased to find that the growing nexus between engineering and business has offered BEE librarians a new setting in which to demonstrate our strengths and expand our relationships across campus.

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