STRATEGIC PARTNERSHIP WITH INDUSTRY TO ENHANCE ENGINEERING EDUCATION AND TRAINING: "THE LEARNING FACTORY CONCEPT"

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ABSTRACT

In modern times, collaboration between university and industry is regarded as an important social experiment in the nation's innovation system [6]. This suggests that joint efforts are needed to concretely enhance society's development, through knowledge transfer and innovations diffusion. This joint paper assesses such collaboration by focusing on what could participants, faculty members, students and companies, gain out of it. In the benefit of all parties, the **Learning Factory** concept is introduced as a sound practice-based curriculum, supported by industry-sponsored capstone design courses through physical facilities for implementing product realization. The result is improved educational and practical experiences that emphasize the interdependency of manufacturing and design in a business environment. The overall outcome of this initiative is to graduate better engineering professionals with the knowledge and skills needed to succeed in the highly competitive world of today and tomorrow. This paper aims at firstly arguing for a practice-based engineering curriculum that balances theoretical knowledge with design, manufacturing, maintenance, market realities, and professional skills; Secondly, showing how to implement "learning factories" at each partner's institution; Thirdly, proposing clear strategies and means for a true collaboration with industry; and fourthly indicating how to improve academics' interest in collaborating with industry.

KEY WORDS

Active learning, practice-based engineering curriculum, senior capstone design projects, learning factories, collaboration with industry, collaborating with academics, engineering education and training.

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INTRODUCTION

There are multiple stakeholders in education: employers, students, faculty, administration, accreditation bodies, and society at large. In order to develop the intellectual capital that will serve as the engine of economic, social and scientific growth in this century, industry and universities should establish strong and direct partnership. New educational paradigms must be developed in order to produce the kind of professional that will drive the new economy. These paradigms should focus not on teaching but rather on learning. One way to enhance learning takes place in settings that go beyond the traditional classroom, where learning takes place through hands-on activities, application of real life problems and through motivation and engagement of students toward academic achievement [7].

During the past two decades, the concept of university-industry collaboration has become an important social experiment in the United States' national innovation system. The idea of university-industry collaboration in the US predates the Civil War with the establishment of the land grant college system, and more realistically with the installation of agricultural experiment stations beginning in 1887. But it is really during the last 20 years, that university-industry collaboration has gained serious policy attention [6]. The fundamental reason for success was the strong partnership created between the partnership faculty, industry and the students in the development process [4].

PRACTICE-BASED CURRICULUM

A key objective was to develop a practice-based engineering curriculum, balancing analytical and theoretical knowledge with design, manufacturing and business concerns. A strong collaboration with industry offers students and faculty real-world challenges. All courses require the practice of communication (written, oral, and graphic), and team-building skills (training, coaching, and leading problem-solving, active listening) needed for industry success [3].

Some departments at various schools are cooperating in offering such interdisciplinary curricula, including mechanical, industrial, chemical, electrical engineering and business. These curricula consist of a progression of manufacturing/design courses, approximately one per term, and allow students to practice engineering science fundamentals in solving real problems [4]. The courses require students to demonstrate the ability to apply their rigorous training in engineering science, design and project management by executing real-world projects defined by an industrial client [3]. Therefore, a capstone design course or course sequence requires senior-level students to apply knowledge gained from previous engineering science, design and laboratory coursework in accomplishing an extended design task. The capstone design sequence facilitates the student's transition from an academic to an industrial environment, and also provides an opportunity to teach and allow students to apply some important topics not covered in traditional engineering science or lab courses, such as ethics, teaming, technical writing, public speaking, and the other topics listed in the version of *ABET Criteria 2000* [3].

The primary stakeholders in the educational process (students, faculty, and industry) have diverse and often conflicting views. While industry stresses practical outcomes, faculty does not everywhere have the needed facilities and tools to guide and help students accomplish steps towards concrete projects. Accordingly, students often ask critical questions about the end use of what they learn in class, and some of them tend to seek degrees on behalf of training and competency. The followings are brief summary of the viewpoint of each stakeholder on the issue [3].

The Industry Viewpoint

Industry seeks to hire graduates with common sense, a positive work ethic, and excellent communication skills. Managers want engineers who can apply the fundamentals to get the job done on time, in a team, and within budget. They want professionals who are willing and able to learn on their own. In a survey done by the National Association of Colleges and Employers (NACE), employers were asked to rate importance of candidate qualities and skills; the results are shown in Table 1 [8].

Quality / Skill	Importance
Communication skills (verbal and written)	4.8
Honesty/Integrity	4.7
Interpersonal skills (relates well to others)	4.5
Motivation/initiative	4.5
Strong work ethic	4.5
Teamwork skills (works well with others)	4.5
Analytical skills	4.4
Flexibility/adaptability	4.3
Computer skills	4.1
Detail oriented	4
Leadership skills	4
Organizational skills	4
Self confidence	4
Friendly/outgoing personality	3.8
Tactfulness	3.8
Well mannered/polite	3.8
Creativity	3.6
GPA (3.0 or better)	3.6
Entrepreneurial skill/risk taker	3.2
Sense of humor	3.2

Table 1: The top qualities/skills that employers look for in new graduates (5=Extremely important, 1=Not important)

It is interesting to note that the first six skills shown in table 1, (Communication, honesty, interpersonal, motivation, work ethics and team skills) are the most important qualities to employers.

The Faculty Viewpoint

Some of common faculty views include:

- By the time they are seniors, students have no curiosity or creativity, and they do not want to learn;
- Students do not remember and cannot apply what faculty lectured about last semester;
- No equipment or space to provide hands-on experiences;
- Need to teach students the fundamental theories and equations. They can learn the practical, non-technical material ("the other stuff") on the job if they really need it;

The Student Viewpoint

Students are not highly motivated by sitting through passive lectures. They cry out for hands-on experiences to complement the classroom lecture experience. Students need a place away from the lecture hall, where they can get their hands dirty. They need a place where they can put the pieces of their education together in their own words, at their own pace and on their own terms.

LEARNING FACTORY CONCEPT

The Learning Factory's mission is to integrate design, manufacturing and business realities into the engineering curriculum. This is accomplished by providing a balance between engineering science and engineering practice. The Learning Factory is, thus, the result of listening to the stakeholders in the education process – industry, faculty and students. Industrial partners say that they want to hire engineers who can communicate, work in teams and who can design and build real hardware, not just computer simulations. In order to do so, graduates must possess strong technical competence in engineering science fundamentals, as well as design and synthesis skills that enable them to effectively apply those fundamentals to solve real problems. Students desperately look forward to exercise their creativity and want to see applications of theory. On their part, faculty aspires to be effective educators but need resources and facilities to reap the full benefits of active learning [5].

Industrial Relations Program

It is highly recommended that universities should establish industrial relations program. The mission of this program is to establish and promote partnerships with industry and other organizations, which will generate sponsored graduate research and development and senior design (Capstone) projects and cooperative work opportunities for the University. The projects will advance the current state-of-the-art and provide sponsoring partners with new technology, information or products to enhance their market position.

The need for active learning facilities

The Learning Factory provides an opportunity to inspire self-directed student exploration. The Learning Factory at Penn State, for example, includes design studios, teaming and conference areas, and manufacturing facilities. Together, these facilities encourage students to actively experience the product realization process in its entirety, from customer need and design concept to finished hardware. In the process, students can experience the following [3]:

- Apply their theoretical knowledge to solve real problems;
- Develop common sense and judgment;
- Learn to work with persons of all motivational and educational levels and develop an appreciation for other disciplines;
- Learn from their errors: *Good judgment comes from experience – experience comes from bad judgment;*
- Discover that everything takes longer and costs more than planned.

Learning Factory Facilities

As part of the Manufacturing Engineering Educational Partnership (MEEP) the University of Washington implemented a Learning Factory (LF) facility as a means of supporting innovative approaches to integrating design and manufacturing engineering education. The facility is an 'activity based' center for the integration of engineering science with 'hands-on' activities and allowing the students to experience cooperative learning by working in teams on industrially sponsored projects. The major emphasis is on design and manufacturing and associated project activities. The facility now supports courses and projects throughout the College of Engineering. The Learning Factory was set up to support courses and activities in design and manufacturing. A faculty and industry committee help define the activities, equipment, and infrastructure that would best serve the courses, student projects, and cooperative learning [1].

Another example of the Learning Factory idea at Penn State, representatives from US industry contributes to students' education process in a number of ways. For instance, guest lectures, by practicing engineers in their field of expertise, add excitement and reality to the classroom. Project sponsors also provide invaluable mentoring to students (and faculty) in the technical and non-technical aspects of real-world projects. The Learning Factory's effectiveness and relevance are continually assessed and challenged by an Industry Advisory Board. This board, which consists of practicing engineers and mid-level managers, helps market the program to future project sponsors, provides curriculum and program feedback, and suggests improvements from the perspective of industrial customers [3].

The Learning Factory at Penn State, for instance, has put in place an infrastructure that makes it easy for all departments to implement industry-sponsored projects, and actively involve industry in the curriculum. The Learning Factory is an on-demand facility that is designed to be used across the curriculum, and across multiple departments. It differs from traditional, highly focused labs owned by a particular department. The Learning Factory is a shared, open access facility, used by as many departments and courses as possible. One of the most educational aspects of the Learning Factory is its melting pot nature, where students from many majors rub elbows and learn from each other. The Learning Factory is continuously monitored by trained personnel and can be scheduled by any engineering class requiring design, manufacturing and assembly facilities. Training classes are offered to instruct students in safety, basic machining, welding and CAD software. The Learning Factory is practically kept open all the time, days, evenings, and weekends for general student use, provided students have the appropriate training certification [5].

Improve academics' interest collaborating with industry and that of companies collaborating with academics.

Throughout the literature, university-industry collaboration is argued as an investment for all concerned parties [6].

Reasons for Firms Collaborating with Academics:

- Solve specific technical or design problems;
- Develop new products and processes;
- Conduct research leading to new patents;
- Improve product quality;
- Reorient R&D agenda;
- Have access to new research via seminars and workshops;
- Maintain an ongoing relationship and network with the university;
- Conduct research in search of new technology;
- Conduct fundamental research with no specific applications in mind;
- Recruit university graduates.

Reasons for Academics Collaborating with Industry:

- Supplement funds for one's own academic research;
- Test the practical application of one's own research and theory;
- Gain insights in the area of one's own research;
- Further the university's outreach mission;
- Look for business opportunity;
- Gain knowledge about practical problems useful for teaching;
- Create student internships and job placement opportunities;
- Secure funding for research assistants and lab equipment;
- Look for business opportunity.

Benefits resulting from collaboration

How do faculty members assess their experience with industry? What kind of benefits do they actually gain from industry-sponsored projects? The followings are beneficial indicators for their motivational concerns [6]:

- Acquired funds for research assistant and lab equipment;
- Gained insights into one's own academic research;
- Supplemented funds for one's own academic research;
- Field-tested one's own theory and research;
- Acquired practical knowledge useful for teaching;
- Created student internships and job placement opportunities;

Benefits experienced by industry

According to industry technology managers, the sponsoring firms realized substantial or considerable benefits in two main areas: access to new research and product development. Particular benefits include the following:

- Gaining access to new research;
- Developing new product process;
- Maintaining relationship with the university;
- Developing new patents;
- Solving technical problems;
- Improving product quality;
- Reorienting R&D agenda;
- Recruiting students.

CONCLUSIONS

A strategically important partnership between higher education and industry is through the integration of design, manufacturing and business realities into engineering education. This kind of partnership could lead to developing a real integrated curriculum with physical facilities allowing for product realization with the cooperation and assistance of many industrial partners.

Under the Manufacturing Engineering Educational Partnership (MEEP) at the University of Washington it has been possible to develop a set of new courses. The outcome allowed not only an increase of the typical curriculum in Industrial and Mechanical Engineering, but also provision of the necessary infrastructure to support hands-on activities in these courses, and successful implementation of the Learning Factory (LF) facility as a means of supporting innovative approaches, integrating design and manufacturing with engineering education. The course development was also planned to provide students with a continuous exposure to design and manufacturing from the freshman through the senior year [1].

The learning factory operational experience at Penn State shows how they are convinced that the traditional, lecture-based approach to engineering education is no longer sufficient. Lectures must be augmented with hands-on practice in the art of engineering. The Learning Factory as a new pedagogical tool provides and fills this emptiness. Its mission is to directly integrate design, manufacturing and business realities into engineering education [3].

The major lesson learned (or perhaps re-learned) at Penn State in ten years experience is that students need to practice engineering, while they are studying it. The fundamental components of the Learning Factory that have had the greatest impact at Penn State and that should be adapted by the higher education institutions are [3]:

- ***Facilities:*** as an open-access, non-denominational, cost effective, active learning laboratory, where students, faculty and industry from all disciplines, experience the realities of design, manufacturing and business practice;

- ***Industry Interaction:*** *as* an efficient infrastructure for actively involving industry in the educational process through student design projects, curriculum improvement and engineers in the classroom; and
- ***Practice Based Curriculum:*** through bringing engineering practice and real-world examples into the engineering curriculum.

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