AC 2007-2280: EDUCATION AND INDUSTRY, A UNION TO FACILITATE ENGINEERING LEARNING

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Education and Industry, a Union to Facilitate Engineering Learning

Abstract

Education and Industry are critical pillars of society, dependent on each other for growth and progress. The Architectural Engineering program at the University of Nebraska-Lincoln integrates a dynamic alliance between these two pillars with a mission of fuelling collaboration and firing the imagination of faculty, students and business alike. This integration has taken place since the inception of the program and its main building, The Peter Kiewit Institute, back in 1996. Initial industry involvement focused on setting up the building as a living lab with informational markers for students to monitor and investigate. Active lecture and laboratory environments are used by faculty and industry involvement as a means for an effective teaching atmosphere. This paper will present this unique setting, how courses are shaped to maximize the setting, and the various teaching methods used to enhance teaching and learning. A detailed description of a representative course, Electrical Systems for Buildings II, will be presented in this paper. Course requirements and expectations, and the multi-integration methods between theory, application and industry will also be presented. Program outcome and feedback from Industry professionals, alumni, and current students, will document how these innovative teaching methods have empowered them to be successful in their field.

I - Introduction

The involvement of industry in education is not a new concept. At Stanford University, a number of courses give students a chance to work on and learn from real problems assigned from real companies and be mentored by industry participants. The Alliance for Innovative Manufacturing (AIM) program is a joint venture between multinational corporations with significant design and manufacturing presence in the United States and Stanford’s Graduate School of Business and School of Engineering. The program objective is to provide members with the latest developments in manufacturing and design. The success of the current industry-sponsored courses has caused interest in the program to spread to other areas of the campus1. Similarly, the College of Engineering and Applied Science at the University of Colorado utilizes the principles of Hands-on Engineering. In the Integrated Teaching and Learning program (ITL), creative, team-oriented problem-solving skills are emphasized. The curriculum is designed to reflect the real world of engineering by being relevant to the needs of society and students alike. The ITL also functions as a living laboratory, with exposed building systems and accessible sensory equipment2.

The Architectural Engineering program at the University of Nebraska-Lincoln, aided by its industry partners and unique living lab (The Peter Kiewit Institute), is an environment empowered to provide students with fundamental and practical building system design. This includes the hands-on learning environment necessary to fully understand the complex issues involved in engineering. Students are given the advantage of learning directly from exposed systems throughout the building, and direct interactions with industry professionals. Engineering curricula must provide relevant examples for students, be based on the needs of society, and
develop methods used by real world engineers\(^3\). The PKI provide this need via visible examples of these technological advances as they change the way we live and work in society.

This paper will discuss the union between education and industry in more details. Section II will describe the setting of the PKI building and its integration as a learning/teaching aid. Section III will discuss an overview of the curriculum leading up to student participation in Electrical Systems for Buildings II and the details the interaction between education and industry. Section IV will discuss the program outcome in terms of the different types of learning styles that were taken into account in the delivery of the course material, and will provide feedback from industry, alumni, and current students. Finally, section V will provide a summary and conclusion.

**II – PKI – A Unique Setting**

The Peter Kiewit Institute (PKI) was designed to be a living laboratory. Nearly all the building systems are exposed to allow students and faculty the opportunity to continue learning even after classes have ended. Students need only to look around to view the applications of class lectures\(^4\). Selected rooms are designed to display functioning mechanical, electrical, and communications systems. Skilled faculty licensed in their respective fields present fundamental engineering theory and concepts using state of the art audio/visual tools and concurrently demonstrate engineering applications via physical and experimental techniques in an interactive learning environment. These interactions give students the opportunity to facilitate the learning of engineering theory along with practical application.

Similar to the ITL (Integrated Teaching and Learning) program, the PKI provides living examples of functional engineering components with which students and faculty can interact. Exposure to the systems and sensors that are integrated into and visible throughout the building stimulates the visualization aspects involved in the design process. Figure 1 shows how some of the systems are integrated in the halls of the PKI. Figure 2 shows a display room and other building systems students can interact with. The Peter Kiewit Institute is designed to help meet the needs of the nation’s technology and engineering firms by providing a top rate education to students interested in pursuing careers in information science, technology, and engineering. More than that, it connects students directly to business and industry.
This business and industrial alliance includes partners in all aspects of industry. In the building systems design aspect it includes: HDR, DLR, Alvine Associates, Peter Kiewit and Sons, Kirkham Michael, and various other engineering-based firms. These members provide students and faculty with resources that include in-class lectures on practical applications of designs learned in the classroom, internship opportunities to students, and funding for research and student support to pursue advanced degrees. Working closely with these partners contributes to the further development of the students’ abilities to function effectively in their chosen fields. Some of these partner companies participate in lab sections of specific courses. Electrical Systems for Buildings II is a perfect example of this involvement. Figure 3 illustrates this alliance in action. Alvine Associates is the company currently overseeing the progress of the lab for this course as will be discussed in the next section.

The instructors of the courses held at the PKI are professionals, licensed in their field and knowledgeable of the systems and technology used in current building systems. They motivate students to research potential equipment manufacturers while developing designs for lab assignments. Their previous industrial working experience provides invaluable insight and guidance into today's industry. This first-hand experience, accompanied with a strong background in theoretical engineering, enables the instructors to answer not only the "how“ but also the "why” questions that arise during the course each semester.

Learning in a structured educational setting may be thought of as a two-step process involving the reception and processing of information. In the first step, external information (observable through the senses) and internal information (arising introspectively) become available to learners, who select the material they will process and ignore the rest. The initial information can be in the form of lectures, demonstrations, building tours, etc. Students have unique methods of processing information based on the way it is presented. Their unique learning style may dictate what information is stored and what is discarded. The second step may involve simple memorization or inductive or deductive reasoning, reflection or action, and introspection or interaction with others. The outcome is that the material is either “learned” in one sense or another or not learned. Students may develop mental images of typical building systems and how they are connected to other building equipment. The display of visual aides in the classroom reinforces the learned material and further impresses the unlearned material on the student. The various laboratories in the PKI building provide various methods of input for each type of learning style.

III – Course Description

Electrical Systems for Buildings II is a mandatory senior level course for students pursuing undergraduate degrees in AE. This course is an integration of lecture and lab comprised of
design theory and practical application practiced by industry professionals. The first part of this integration, the lecture, is presented by a skilled faculty member who is a licensed electrical engineer. Topics including AC power system analysis, power quality (harmonics), voltage drop, machinery principles, and transformers are covered during the first half of the semester. Following these topics the instructor presents the concepts of fault analysis, grounding, coordination, DC machines, and synchronous machines. The following subsections describe the integration of industry and teaching to provide students with the best education.

A – Classroom Environment

The course lectures take place in a multipurpose living laboratory classroom equipped with a variety of visual aids to assist both the instructors and students in presenting and understanding the application of various types of equipment used in the design development of electrical systems for buildings. One of the main features is a complete off-line replica of an actual building electrical distribution system as shown in Figure 4 and Figure 5, including a main distribution panel, motor control center, step-down transformer, and branch circuit lighting and power panels along with actual circuit breakers, disconnect switches, fuses, conduit and conductors to interconnect the entire system. This replica system allows the student to see the physical connections and sizes of equipment to facilitate practical and rational design methods. The classroom is also equipped with various types of lighting systems and exposed mechanical equipment to provide further insight and system wide coordination. State of the art visual and audio projection systems are utilized in the classroom for both lecture and laboratory instruction. Course interdisciplinary design projects lead to a better understanding of the equipment used in the industry.

During classroom lectures, professors have the advantage of using multi-media setting to display images, diagrams, and other documents. Exposed equipment in the classroom can be dismantled and the function of the individual pieces can be explained on a theoretical level. Figure 5 is an example of this equipment setting. Professors can point directly to the most important pieces that comprise a good building electrical design and describe the ideas behind their coordination with other system components. Students are encouraged to observe and handle this equipment as shown in Figure 6.
B – Laboratory Environment – Industry Involvement

The laboratory part of this integration is presented by an industry professional and partner of the PKI in association with the course instructor. Industry professionals provide students with insight and practical applications of the theoretical concepts they have acquired. The goal of the lab is to reinforce the material covered in the classroom and to develop an understanding of building power system design and effective production and design methods. At the beginning of the semester, the class is presented with preliminary plans for a building previously designed by the industry professional dictating the lab. Students are then asked to complete a series of design tasks each week in the order they would occur in a professional environment. Each week the students are issued a set of drawings and necessary information to complete the task. They are asked to analyze, design and document their results and show their designs on the drawings providing all information pertinent to a practical and efficient design.

Beginning with bubble diagrams and “rules of thumb,” students are asked to calculate initial estimates of power consumption for the building. Later they will size required equipment and select locations to optimize the performance of the system. Lighting and receptacle loads are calculated for the sizing of over-current protection, high and low voltage panels, and feeders. Students are then asked to circuit the equipment, including lights, receptacles, and other mechanical devices, and record their data on appropriate panel schedules. Each week one or more of these tasks is required to be completed according to the specified deadlines. Students present their solutions in front of the classroom so the instructor and other students can provide feedback and recommendations for improvements. The actual designed systems are then presented in the classroom to further enhance the student's process and methodology for such designs. At this point during the design review, the instructors and other class members can ask questions regarding the logic of the design and provide additional feedback to presenters to facilitate any necessary improvements. Later in the course, students provide voltage drop and fault current calculations to ensure the system is designed for safe and efficient operation and is meeting local, state, and NEC code requirements. As the design approaches its final steps, discussions related to energy conservation, alternate renewable resources and optimal performance is discussed. Finally, a tour of the actual building takes place. This allows the students to observe the actual physical system and compare to their own design. This process is
also used to highlight the fact that broad building systems knowledge is required to coordinate with mechanical, structural and other systems. Figure 7 shows a section of the building interior and student participation.

In addition, lecture guest presenters are also coordinated with partners of the PKI to present on specialized topics such as grounding or harmonics. Participating engineers are invited to present their practice and provide hands-on measurements and demonstrations of related topics to students. Martin Conroy of Computer Power and Consulting\textsuperscript{11} presented one such topic during the fall of 2006. His presentation included power harmonics and grounding techniques and technologies. Figure 8 shows an actual demonstration of the type of clothing required to handle electrical systems. Incorporating industry professionals in this manner provides the students with a broader view of the industry to which they will soon belong. Aside from the technical information, students are involved in discussions regarding professional and ethical responsibilities in their fields.

Figure 7. Students tour of the designed building

Figure 8. Demonstration of clothing required to handle actual electrical systems and outside building grounding measurements.
C. Laboratory Environment – Teaching Methods

This laboratory setting introduces the students to the production aspect of the industry and promotes spatial awareness and equipment functionality. During the course of this lab, students also further develop the ability to function in groups in a collaborative effort. According to Richard M. Felder, cooperatively taught students tend to exhibit higher academic achievement, greater persistence through graduation, better high-level reasoning and critical thinking skills, deeper understanding of learned material, more on-task and less disruptive behavior in class, lower levels of anxiety and stress, greater intrinsic motivation to learn and achieve, greater ability to view situations from others' perspectives, more positive and supportive relationships with peers, more positive attitudes toward subject areas, and higher self-esteem. Another nontrivial benefit for instructors is that when assignments are done cooperatively, the number of papers to grade decreases by a factor of three or four, allowing the instructor more time to focus on research topics and lectures that can influence building system design. Cooperative learning has repeatedly been shown to be more effective than the traditional individual/competitive approach to education.6

As part of the group setting, time management and the division of labor for each task become an issue and must be resolved by the groups. Each week students are evaluated on their progress and instructors keep an open door policy for the students to ask questions as they arise during the course. Presenting realistic and interesting technological and socially relevant problems and asking the students to contemplate approaches to solving them and assuring them that will do this constantly as engineers may be the best way to impress on them the need for lifelong learning.6

IV – Program Outcome

A - Accommodating Students Learning Needs

Using the classroom and building as living visual aides to teach the Electrical Systems for Buildings II Course allows the students and teachers opportunities to instruct and learn via multiple methods. Each student is unique and may process information more efficiently using different methods than other students. Visual learners may benefit more from visual aids or things they can see, while auditory learners thrive on lecture and anything they hear. A unique physical environment as set up by the PKI environment satisfies a sensory learner’s needs as shown in Figure 9.

Figure 9. PKI’s exposed systems.

Active learners benefit from group activity and experimentation that take place in the laboratory. Some of the concepts taught in the course may be difficult to teach and learn using one method solely. The unique laboratory provides the instructor with versatility to select the appropriate teaching
technique for the subject or idea being presented. The classroom becomes a three dimensional, interactive, and operational visual aide. Professors can tour the building with the class and conduct lectures in the hallways providing time for students to ask questions about the systems and equipment. Sequential learners who thrive on acquiring information or techniques in discrete pieces benefit from the classroom experience also due to the isolation of the individual topics and processes comprising the course curriculum. Intermittently throughout the course, Global thinkers are satisfied by discussions involving the relevance and impacts of the topics on other building and environmental systems.

B – Perspective and Feedback

The success of this program setting and involvement with industry can be measured in many ways. One of which is to seek feedback to determine the impact the course and program has had on its participants. The following subsections will discuss the feedback from industry professionals, alumni, and current students.

1. Industry Feedback

Ken West, a principle at DLR Group, noted that Architectural Engineering graduates are not only quality people, but they are well prepared to enter building design industry. Prior to Architectural Engineering programs companies needed to find people in traditional Electrical and Mechanical Engineering programs. These were qualified professionals, but they were generally unprepared for building design, and uninterested in buildings. Architectural Engineering graduates have specific interest buildings and their backgrounds are suited to mechanical and electrical aspects of building design. After entering the industry, they require very little training to assist company staff effectively and begin designing building systems.

Jason Rohe, a Senior Electrical Engineer at Dale Schnackel Company commented on the electrical engineering course. He noted that prior to courses such as Electrical Systems for Buildings, the primary education of an electrical engineer was in electronics, and did not provide the background required for the design of AC power systems, electrical distribution equipment, and other building systems. Jason noted the speed and ease graduates from architectural engineering programs had as they adapted to their roles at Dale Schnackel Company compared with traditional electrical engineering graduates. Jason also stressed the importance of students seeing how a system is actually installed versus drawn on paper. Jason noted the effectiveness of the class at developing communication skills necessary to intelligently ask and answer questions with clients.

Doug Alvine, President of Alvine Associates and co-instructor of the course, noted that the approach and communication of the class is real world based by default. The focus is to solve engineering problems you will see in the field and the structure of class with professionals and professors both teaching automatically integrates both practice and theory. Students, interns, graduates, and professionals that have taken the course can attribute a portion of their success to this class. The class is not only beneficial to electrical engineers, but can provide mechanical engineers with the necessary tools to be effective in the electrical field. The relationship building between students, professors, and professionals on a first name basis is a lasting benefit. It
allows all of the class participants the opportunity to expand their circle of colleagues and potential coworkers. Doug also pointed out that the most beneficial aspect about teaching the course is how much he learns while he teaches through questions from students. Having to think and work through the solutions to their questions provides an opportunity for continued education and growth and as an engineer.

2. Alumni Feedback

Alumni’s interviews have provided feedback on the success of this course and its relevance to their goals in Architectural Engineering. Sarah Nieves, an alumnus, stated “In engineering this type of learning environment is extremely useful, if not necessary, due to the complexity of building systems. As an energy conscious mechanical engineer, integrating all building systems is of the utmost importance to me. Having a thorough understanding of electrical, structural and fire systems is crucial. She also pointed out the positive impact that selecting fixtures, sizing panels, feeders, transformers, designing circuits, and loading panels had on her development of expectations as an architectural engineer. Hands-on applications allowed her to directly interact with equipment and processes. Sarah says she feels more confident and comfortable in her role today because of the classroom learning environment, which eased her transition from student to professional. Chilekwa Chongo, another alumnus, thoroughly enjoyed learning and participating in the step-by-step processes of formulating a good electrical design during the lab. Descriptions of real-life examples provided by the professors were a helpful learning experience for Chilekwa. Mike Merwald, an alumnus, stated that his favorite aspect of the course was his interactions with Doug Alvine of Alvine Associates, and the real world perspective gained from those interactions. Mike found benefits in meeting with a group to accomplish the weekly assignments in the laboratory.

C. Current Students Feedback

A survey of current students provided similar feedback as stated by alumni. Most students agree that the unique atmosphere is stimulating and informative. They agree that it is easier to understand the topics of the lectures when the visual aides are part of the permanent classroom. Varying the teaching style and media has also kept students “on their toes”. Most of the class participations believe Electrical Systems for Buildings II will increase their ability to communicate effectively with professionals. Brian Isley, a senior, thought the semester-long design project would be the most beneficial part of the course. He hopes it will give him a competitive advantage in the industry among his peers by familiarizing the practices presented by industry professionals, and introduce him to using the NEC as a design guide.

Kent Krouse, a fifth year student thought the laboratory and classroom setting was useful to him as a young designer because he could physically see the items discussed and designed on paper. The visual aids provided in the classroom expanded his awareness of the actual products in industry and their physical dimensions. This improved the approach Kent took to short circuit calculations and equipment sizing during his internship the previous summer. Kent stated “I can also see the benefits of the class and lab setting for those who had not had an internship as the materials covered were very similar to young engineer’s first few months of design work.” Clayton Miller stated “The Electrical Systems for Buildings class really improved my
understanding of the overall system design process. The lab portion was especially helpful because it gave me the opportunity to exercise some of the practical skills that I could actually use as a professional. I liked the class because it helped me understand how to specify and schedule electrical building system components. This aided my development of the vocabulary and visualization skills necessary to communicate effectively in a professional engineering environment.” Craig Johnson found that familiarizing himself with the codes and professional design practices very influential. He enjoyed learning the iterative processes of balancing power systems and seeing the basic design evolve into a finished product.

V – Summary and Conclusions

This paper presented the relationship between Education and Industry at the University of Nebraska – Lincoln’s Architectural Engineering program. This relationship is of paramount importance since education and industry are critical pillars of society that depend on each other for growth and progress. The Peter Kiewit Institute, where the Architectural Engineering program is housed, is a living example of this union where nearly all the building systems are exposed to allow students and faculty the opportunity to continue learning even after classes have ended. Participation of industry professionals in the development of this lab and in the continuing contribution to education via lectures, resources, and hands-on activities facilitate student learning. Methods of accommodating different learning styles using the Living laboratory as an interactive visual aide were introduced. The importance of varying teaching techniques to teach a course with a unique curriculum such as Electrical Systems for Buildings II was discussed. Finally, feedback from industry, current students and alumni describe the strengthening of their engineering field due to PKI environment and the method used to teach engineering courses.

Bibliography

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