AC 2012-3527: A LABORATORY-BASED, PROBLEM-SOLVING PEDAGOGY PREPARES STUDENTS TO HIT THE JOB MARKET RUNNING!

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Introduction

The purpose of this paper is to provide insight into the "laboratory/design based problem solving learning environment" that has been developed with financial and technical assistance from local industries. The discussion will also identify how the "need" for this type of project based curriculum became obvious. Four prerequisite courses are briefly described before focusing on the project based capstone course. These four courses provide the students with the technical skill sets needed to succeed in the senior level capstone course. Accomplishments and outcomes from the student perspective, the University perspective, and the industry perspective will also be shared.

Our advancing world of computer integration, process control, industrial automation, and telecommunications requires technical problem solvers and knowledgeable decision makers. "The activities of problem solving and decision making are closely intertwined",[1] and both skills can effectively be learned through project based capstone courses. Industrial partnering has enabled the development of a state-of-the-art power and automation curriculum and project based problem solving learning environment for our students and also for the communities beyond campus.

The laboratory/design based problem solving learning environment is organized into clusters. These clusters are equipped with components such as computers, printers, programmable logic controllers, sensors, pneumatic valves and actuators, mechanisms, rotary index tables, hydraulic cylinders, electric motors, and vibratory feeder bowls. In the senior capstone course, participants are grouped into teams that design and solve realistic industrial problems such as parts sorting, quality control, clamp and work circuits, material handling, and component assembly.

Students find this capstone level course both challenging and rewarding as they are required to integrate subject matter learned from many courses throughout their entire degree program. This highly developed advanced course integrates competences mastered in other courses such as computer-assisted design, spreadsheet and database utilization, material processing, computer programming, and ergonomics. Students actually use every lab in the building (CAD lab, welding lab, etc.) but the focal point is the complex yet inviting industrial problem solving lab. This unique design based senior course continually challenges the student to advance, grow, internalize and demonstrate the new knowledge and techniques they are learning.

Problem Solving Learning Environment

The freshmen level courses that utilize the problem solving learning environment are electricity/electronics and mechanical power conversions. The first course focuses on electrical components and concepts. Students learn how to mathematically calculate electrical variables such as current, voltage, and resistance. Then they physically assemble circuits and test their mathematical results with electronic instrumentation. In another activity, students calculate the frequency needed to drive an electric motor at a several different speeds (r/min). The students then program a variable speed drive unit and use a strobe light to determine if their calculations were correct.

In the mechanical power conversion curriculum, students gain insight into components such as bearings, gears, chain drives, motors, lubrication, and vibration analysis. The learning lab provides hands-on problem solving activities in each of these areas. The purchase of specialized mechanical power transmission learning modules were subsidized by local industries who realized the need for engineers and technical managers with problem solving abilities.

The sophomore level fluid power course also makes extensive use of the facility. This course provides an in-depth investigation into hydraulic and pneumatic systems. Beginning at the system level, students gain an understanding of how the major components function together to make the system work properly. After the big picture is understood, the focus changes to the specific components such as pumps, compressors, manual and solenoid activated directional control valves, pressure and flow control valves, cylinders, motors and conditioners.

Industrial partnering has equipped the learning environment with two state-of-the-art hydraulic trainers where students work with all of these components. The pneumatic modules were a project based assignment designed and fabricated by another class from donated components. Learning is greatly enhanced in this fluid power course from the touch, the sound, and the motion of the actual components being studied.

The junior level process control course utilizes Allen-Bradley programmable logic controllers (PLC) and the accompanying RSLogix ® software. A dozen clusters are utilized for the hands-on problem solving component of this course. Each cluster is composed of a desktop computer linked to a Micrologix 1000 ® PLC module which was also designed and fabricated as a project in another class. An organized kit includes typical industrial inputs such as push button switches, limit switches, and both inductive and capacitive proximity devices. The kit also includes typical industrial outputs including lights, buzzers, motors, and solenoid activated pneumatic directional control valves.

Students are given a project assignment in the form of a problem statement. The problem statement identifies exactly the sequence of events that must occur and what inputs/outputs (I/O) are specified. From this problem statement, each student develops their own software solution via the scientific problem solving method. Compiling, downloading, wiring I/O and testing their solution takes only a few minutes. This quick feedback is crucial to the learning process. If the program does not work properly, they can modify it and try their new solution without consuming excessive lab time.

Typical process control projects include a traffic intersection where the traffic lights and pedestrian walk signs are accurately sequenced. Another programming and I/O project is a parking garage that tracks vehicles entering and exiting, and illuminates either a "Lot Full" or a "Room Available" sign based on the garage's capacity. One of the more challenging problem solving PLC based projects is to develop the logic for a pneumatically powered press. In this safety related scenario, both hands must push separate buttons before the press is allowed to close. The tricky aspect is that if the press operator tapes or ties down one of the buttons, the press will not respond! A small pneumatic cylinder controlled by a solenoid directional control valve simulates the press motions. A total of eleven problem solving projects are utilized in this course.

The PLC modules and I/O devices used in this junior level course were specified at the same voltage and have been designed for patch-cord assembly. This allows the students to focus on the job of learning the software and interfacing the I/O devices without the danger of injuring themselves or the components. In the capstone course, this safety net is not present and more time is spent on these concepts.

Armed with the knowledge and abilities in the prerequisite courses discussed above, students embark on a truly challenging project based problem solving adventure. The senior level capstone course is entitled robotics and automated material handling. Students find this course both demanding and rewarding as they are required to integrate subject matter learned from many courses throughout their entire degree program.

This past semester a local company provided a suggestion that became the focal point of a student group project. This company prepares a processed chicken product that is sold nationally. It appeared that one of their suppliers used metal staples to seal cardboard boxes and somehow one of the staples ended up in a food product that resulted in litigation. They asked if we could develop a machine that could monitor a line of food products for metallic objects. If metal was found, that product would be physically ejected without slowing down the packaging line.

A four student team designed and fabricated a machine that used proximity sensors and pneumatic cylinders to accomplish this goal. They used golf balls instead of chicken products. Some of the golf balls were coated with aluminum foil to simulate a contaminated product. Of course this machine was not going to be used by the company on the packaging line. But it did serve as a proof-of-concept prototype for one that was professionally built and installed by the company.

Another student group used a suggestion from a metal casting company that would check components for proper dimensioning and sort out the rejects. This project based problem solving course is very encompassing, time consuming, and rewarding. It continually challenges the students to advance, grow, internalize and demonstrate the new knowledge and techniques they are learning.

Specific Pedagogical Innovations

Specific pedagogical innovations that are utilized in this laboratory based, problem solving learning environment included the following models.

> Proactively use a variety of active teaching and learning techniques.
>
> More qualitative than quantitative. Merely assigning more or less work based on a learner's ability is typically ineffective.
>
> Rooted in assessment. Evaluation is no longer predominately something that happens at the end of a chapter to determine "who got it". Assessment routinely takes place to determine the particular needs of individuals.
>
> A teaching style that provides multiple approaches to content, process, and product. <u>Content</u> is the input, what students learn; <u>Process</u> is how student make sense of the ideas and information; and <u>Product</u> is the output, how students demonstrate what they have learned.
>
> Student centered. Learning is most effective when experiences are engaging, relevant, and interesting.
>
> A blend of whole-class, group, and individual instruction.

In addition to these pedagogical models, the overarching concept is one of **problem based learning**. Dutch comments that "the mainstay of traditional teaching is the lecture / listen ritual".[2] Problem based learning, also known as problem solving learning, is as well an old fashion alternative that helps students develop critical skills needed today such as the ability:

- to think critically, analyze and solve complex, real world problems;
- to find, evaluate, and use appropriate learning resources;
- to work cooperatively in teams and small groups;
- to demonstrate effective verbal and written communication skills;
- and to use content knowledge and intellectual skills to become continual learners.

According to Bound & Feletti, "problem-solving learning is older than formal education itself, namely that learning is initiated by a posed problem, query, or puzzle that the learner wants to solve".[3] In problem solving learning, complex, real problems motivate students to identify and research concepts and principles they need to know in order to progress through the problems. Students work independently or in small learning teams as they acquire and integrating information in a process that resembles that of inquiry.

Students soon see that "learning is an ongoing process and that there will always be new learning issues to be explored. Because they learn concepts in context, they are more likely to retain that knowledge and apply it appropriately in novel situations".[4]

The Need

Why require project based and/or design problem solving courses? Technology is no longer something limited to a few individuals. It is an integral part of everyone's life. As technology advances, quality employment opportunities are seeing a more technically illiterate population. While industries once competed against their neighbors, now our competitors are other countries that can produce quality goods and products at far lower cost.

Traditional approaches and strategies that worked in the past are not the panacea for the future. "Facts and knowledge can only go so far. Tough problem solving requires the ability to define the true problem, analyze the possible causes, create options, select the most feasible option, and then implement it". [5] Industries need problem solvers, they need team players, and they need innovative minds. This may only be achievable through progressive curriculums and effective partnerships between industries, universities, and government institutions. Those partners that make the best investment in technically competent employees are going to be those that prosper in the 21st century.

Students respond with enthusiasm when lectures and tests are supplemented by labs in which they solve problems from industry. As the theoretical knowledge is internalized, students become intrinsically motivated search engines to fuel their own intellectual growth. To effectively connect with students at this level and prepare them for the future we need real-world skills and experiences.

In order to modernize our program, we need to focus on both the curriculum and the facilities. Strong industrial support in the form of money, equipment, and advice enabled significant facility upgrades. It has been these same industrial partners that have "enabled [engineering] to weather the fiscal storm better than others. Some departments have much more discretionary funds than others". [6] While substantial amounts of faculty time and effort were required for curriculum revisions, historically lecture and theory based courses, have been dramatically upgraded to reflect the concepts and skill sets need by today's graduates.

Outcomes

Pretesting identified little difference between those students who took the lecture only course and those who also took the course with a laboratory component. Quantifiable comparisons from those with the lab component show a substantial increase in quiz/test scores, and final course grades. In addition, the laboratory sessions served as a classroom assessment technique providing real time validation of the problem solving pedagogy.

University administrators routinely visit the project based problem solving learning environment with distinguished guests to highlight the innovative learning approach. The facility has also assisted in topic development for faculty grant writing. All of the courses that utilize the facility are full and students genuinely look forward to each class.

In fact, students become so enthralled in the problem solving process they loose track of time. Local industries frequently suggest the senior capstone projects as a manner to help them solve some of their prototyping issues. An additional outcome has been a continuous supply of companies willing to serve as "hosting firms" for our internship program.

Conclusion

Skillful teaching technique must be coupled with careful preparation and a thorough understanding of the subject matter in order to produce an open, dynamic environment that will foster problem solving and effective learning. Global competitiveness requires that graduates be technically literate team players, and analytically proficiency problem solvers. Requiring students to apply their math and science via hands-on problem solving, and requiring professional internships will produce a better prepared graduate.

Just as the task of learning is an individual process, the role of an educator is a multifaceted occupation, and for those in engineering and technology, the challenge is even greater. Few occupations are as essential to the advancement of a technical society as that of an educator. It is through quality education that we prepare individuals for the challenges of today and those of tomorrow.

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