An Interdisciplinary Program and Laboratory for Printed Circuit Board (PCB) Design and Manufacturing

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ABSTRACT
Oregon State University and Merix Corp. (Forest Grove, OR) have initiated a cooperative University-Industry program for hands-on education of engineering students. This interdisciplinary program spans the Departments of Chemical Engineering (ChE), Electrical and Computer Engineering (ECE), Industrial and Manufacturing Engineering (IME) and Mechanical Engineering (ME) and focuses on the design and manufacture of a printed circuit board using actual PCB manufacturing equipment in a new PCB laboratory housed at OSU. Curriculum development will include courses to develop "core competency" in each major discipline, and a capstone PCB Design and Manufacturing laboratory course which will focus on interdisciplinary group activities aimed towards a common goal -- the production of a printed circuit board. Educational programs will be offered at the engineering technology (local community colleges), advanced undergraduate and graduate levels (OSU). The laboratory development and operation is a cooperative activity between OSU and local industry to promote education and research in the electronics industry.

INTRODUCTION
The 50th Anniversary issue of Chemical Engineering Progress (January, 1997) provided many articles related to chemical engineering "then and now". In one of those articles David Koch looked at the role education will play in shaping the future of chemical engineering (1). He mentioned the beginnings of three "trends" which he thought would be very important. The first was professional education, which he described as "...exposing students to actual industrial practice provides the best educational laboratory for learning design, problem-solving, and teamwork, among other things." The second was interdisciplinary, which he suggested was a natural result of the broadening of the field of chemical engineering to include new growth industries. The third was the electronic classroom, where very fast and cheap computers would make the virtual chemical engineering laboratory a possibility. All of these concepts are addressed with the curriculum development project described in this paper.

There are a number of excellent examples where programs have been developed to address a change in undergraduate engineering education to emphasize the practical experience and interdisciplinary teamwork concepts suggested by industry (2 - 7). The unique aspects of the current project are that the curriculum and laboratory development focus on two distinct philosophies:
• Providing the students an interdisciplinary experience in which the unique talents of the individuals (their "domain competencies") are used to solve problems in a team setting. For this mode of operation to be effective, each team member must have a firm grasp of the overall process and understand the capabilities of their team members. That is, everyone must have the "big picture" so they can work toward a common goal, but it is not necessary for them to comprehend how to address each individual problem.

• The common goal in this case is a product -- the printed circuit board. The groups must realize that their success or failure lies in their ability to deliver a product in a timely manner and to specifications, and that they are a key link in the process. If they fail, the operation can proceed no further.

The traditional university environment is “departmentalized” and provides for little cross-discipline team experience for graduates preparing to enter industry -- which is team dominated. Additionally, university laboratory experiences tend to be oriented toward unit operations rather than an integrated process. An example of a “unit operations experience” is an electrical engineering course on the principles of circuit board design, with a supporting laboratory where computer-aided design tools are used to design circuit boards. The student typically never interacts with those who manufacture and test the circuit board designed. In an "integrated experience" students from the electrical, chemical, industrial and manufacturing engineering departments would all complete unit operations oriented courses and laboratories where their "domain competency" is developed in the same manner as in the electrical engineering example above. Subsequently, interdisciplinary teams of students would be formed in which each student would bring their "domain competency" to the team. Each team would then participate in an integrated process that encompasses design and manufacture of a product (in this example a printed circuit board). This experience mimics industrial practice.

GOALS AND OBJECTIVES
The goal of this project is to establish an integrated printed circuit board (PCB) design and manufacturing facility, and develop curricular material to provide interdisciplinary student teams a completely integrated PCB design and manufacturing experience. The following objectives have or will be addressed:

Objective 1: Complete the design of the PCB laboratory facility with the advice and guidance of the Electronics Manufacturers Association (EMA) of Oregon.

Objective 2: Procure and install the equipment and software required for startup of the facility. The majority of the equipment will be provided by EMA members.

Objective 3: Develop and integrate domain specific courses in Electrical and Computer Engineering (ECE), Industrial and Manufacturing Engineering (IME), and Chemical Engineering (ChE) that prepare students for an interdisciplinary team experience in PCB design and manufacturing. Each of these three courses will focus on engineering principles associated with PCB design and manufacture and the use of software tools and laboratory equipment available to reinforce these principles.
Objective 4: Develop and integrate into the curriculum a **capstone laboratory project course** that will provide *interdisciplinary student teams* with the experience of design and manufacture of a functional printed circuit board.

Objective 5: Develop curricular materials (e.g., multimedia computer models; lecture materials and problems, etc.) that use printed circuit board design and manufacturing as a vehicle to illustrate engineering principles such as mass and energy balances, fluid mechanics, statistical process control, etc. These materials will be used in the program at OSU and will be made available to the educational community, in part through the development of an *OSU PCB Laboratory Home Page* on the WWW.

Objective 6: Develop the capability to provide small lots of custom printed circuit boards at cost for use by other educational institutions that have neither the facility to produce them or the funds to commercially procure them.

Objective 7: Develop a relationship and training program with the local community colleges, to provide training in the maintenance and operation of PCB manufacturing equipment. This is in direct response to the needs of Oregon industries.

**EDUCATIONAL IMPACT**

The educational impact of this project should be far reaching because it will: 1) improve the undergraduate engineering curriculum at Oregon State University, 2) provide a mechanism for interaction with the local community college, 3) provide a mechanism for interaction with other educational institutions, 4) provide for continued long term interaction with industry, and 5) will provide a model for laboratory and curricular reform.

1) Improvements to the undergraduate engineering curricula at OSU will be provided through establishment of an integrated printed circuit board design and manufacturing laboratory spanning the departments of ECE, IME, and ChE, and development of three new lecture/laboratory courses, and a new interdisciplinary capstone course. The proposed course titles are:

- ECE Principles of printed circuit board design and manufacturing
- IME Principles of printed circuit board design and manufacturing
- ChE Principles of printed circuit board design and manufacturing
- Printed Circuit Board Design and Manufacturing Laboratory

In the first three lecture/laboratory courses **domain competencies** will be developed and engineering principles will be demonstrated with PCB manufacturing equipment and software tools. As a result of this course the students will have produced a functional product. There is no course or sequence of courses at OSU that provides this experience. The capstone laboratory course will provide new exposures and experiences in areas not typically addressed in specific domains. For example, statistical process control (SPC) and design of experiments (DOE) will be addressed in the capstone course but are not addressed in either the chemical or electrical engineering curricula.
2) The local community college (Linn-Benton Community College - LBCC) will be able to provide operator and maintenance training for PCB manufacturing equipment with the facilities established through this project. In addition to developing programs in the maintenance and operator training areas, LBCC will also be able to provide assistance to OSU in the maintenance of the facilities through their student projects.

3) This project will benefit other educational institutions in several ways:
   - provide multi-media modules that demonstrate basic engineering principles such as mass balances, through the vehicle of PCB manufacturing facilities.
   - provide a remote manufacturing facility for small lots of PCBs at cost of materials.
   - enhance the educational experience of students by dealing with a remote manufacturing facility through electronic media.
   - provide a model for development of interdisciplinary student team activities that reflect a real design and manufacturing process

4) This project has grown from industry and university interaction. The formation of the PCB Design and Manufacturing Advisory Board, and the significant commitments of equipment and support from the industry ensure continued long term industry interaction.

5) This unique program that addresses a critical area of technology and educational reform will serve as a model and provide valuable materials for educational institutions concerned with similar issues.

SUMMARY
Objectives 1 and 2, to a large extent, have been met. The interdisciplinary team of educators are presently pursuing completing Objectives 3, 4, and 5. The projected implementation of the domain specific courses is January, 1998. The PCB laboratory facility, which would be used in the capstone laboratory course, is already under development.

In summary, there are two major innovative aspects to the project that is currently under development at Oregon State University:

- Students participate in an interdisciplinary experience where the unique abilities of the individuals – their domain competencies – are used to solve problems in a team setting.

- The learning environment created in this project offers a unique educational pedagogy. Rather than the usual practice of focusing on an isolated portion of a much larger project, the capstone laboratory requires that the student teams effectively combine their individual processes to produce an actual product -- the printed circuit board. The groups must realize that their success or failure lies in their ability to deliver a product in a timely manner and to specifications, and that they (each of them) are a key link in the process.

The unique aspects of this educational experience are, in fact, the normal operating procedures for most industrial processes. Therefore, the "implied" main objective of this project -- to provide a B.S. engineering graduate better prepared for the challenges of a position in high technology industries -- is a direct benefit of the project's success.
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REFERENCES


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