Industry Internships as a Tool for Curriculum Development

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Abstract

Industry surveys indicate that new engineering graduates lack important skills. University curricula have been slow to respond to industry needs. In the summer of 1997 I participated in a month-long industrial internship. While opportunity was provided for making research contacts, the main purpose was to provide first hand exposure to what engineers do and what skills they need. By expanding this type of internship opportunity to involve more faculty, MTU hopes to accelerate the pace of curricular change. This paper describes the activities that comprised this internship as well as the skills observed to be most important. With a few exceptions, my list of skills matches the lists derived from employer surveys. Based on these observations, my recommendations for curriculum change are: (1) provide more opportunities for students to develop the soft skills (for example, by requiring more practical team projects); (2) explicitly teach process skills, such as problem solving and project management; (3) emphasize the basics in engineering science courses and how to apply them to a variety of problems; (4) offer more systems courses to help students deal with the complicated products and organizations they will encounter. The internship has impacted my teaching and service activities in several ways. The paper concludes with some suggestions for more tightly integrating the internship to curriculum development.

Introduction

In some industrial quarters, there is growing dissatisfaction with the types of graduates coming out of engineering colleges. Published surveys repeatedly indicate that engineering graduates are deficient in several areas industry finds important.[1,2] University curricula have been slow to respond to the demands of these important customers. Michigan Tech has several industry advisory boards that relate their priorities and suggest directions for curriculum modifications. However, the faculty, who are ultimately responsible for making changes, often have different priorities. Survival and success of our university may depend on whether we can adapt to the needs of industry.

The idea for this internship germinated from discussions of MTU's National Advisory Board. By placing professors in industry settings for a short time, the NAB hoped that we would better appreciate their needs and become agents of curricular change. (The concept is similar to the Visiting Engineering Faculty Program being launched by ASEE and the Industrial Research Institute[3]). MTU's Dean of Engineering Bob Warrington and a NAB member from Boeing, Fred Mitchell, initiated this pilot internship. During the summer of 1997 I spent a month at the Boeing Company. Like many internships, one of the purposes was professional development, and opportunities to visit research facilities and make contacts were included. However, this paper focuses on what was learned about engineers and their skills and implications for curriculum revision.

Internship Format

Boeing's Fabrication Division served as my host. The Fabrication Division makes components and sub-assemblies for airplanes, and I spent most of the month at a group of factories located 30 miles south of Seattle. I spent approximately one week touring and discussing Manufacturing Research and Development projects, another week with an Integrated Product Development team, and a third week participating in a lean manufacturing improvement workshop. The remaining time provided brief exposure to activities such as environmental affairs, producibility, business systems software implementation and training, and knowledge based product design. Manufacturing activities were heavily emphasized, which matched my background of teaching manufacturing courses in our Mechanical Engineering department and conducting machining research.

One of the difficulties of setting up the internship was to make it somewhat immersive while giving exposure to a variety of job functions. The lean manufacturing improvement workshop was the most immersive activity. I was a member of a team attempting to improve cycle time in a mold machining operation. I participated rather than simply observed. Other worthwhile activities were sitting in on some of the meetings, for example a dry run for a critical design review. While we tried to avoid too much touring, some of the tours were worthwhile, particularly when engineers close to the operations pointed out the problems and places engineers are involved in making improvements.

Important Skills for Engineers

Through first hand observation and second hand discussions with engineers I found that successful engineers need a variety of soft and hard skills.

Teaming and People Skills Several young engineers observed that one of the biggest differences between working and school is that in school you competed against your classmates whereas at Boeing everyone helps each other. For effective teaming the engineer must respect the contributions and points of view of teammates.

Several engineers I met stressed the importance of humility. More and more engineers are being re-located to the factory floor to be close to the operations they support. Some engineers expect a more white-collar environment. It was pointed out that mechanics know more about their jobs than engineers do and that engineers should not force their ideas on mechanics. Introducing new ideas takes time and negotiation. As an example, Manufacturing Research and Development (MR&D) developed a one shot drill and countersink tool for final assembly mechanics. The mechanics accepted the new tool without much difficulty but would not use the tape that's recommended for preventing marring of the body surface. It will take time to understand the mechanics' concerns and to show them the importance of using the tape (if, in fact, it is important). Another aspect of humility is to ask questions. New engineers have a lot to learn and pretending to understand when they don't will only slow the learning process.

Communication Skills One of the most important communication skills appeared to be listening. As one machinist pointed out, "Everybody has to say their piece. They won't listen to what anyone else says until they feel they've been heard. They will repeat themselves over and over until they feel they've been heard." Another valuable skill is to explain complex concepts clearly and concisely. Engineers communicate with people at different levels in their organization who require different amounts of detail. By explaining concepts at the appropriate level, miscommunication and repetition can be reduced. Perhaps the most important aspect of communication skills is just to do it. In the lean manufacturing improvement workshop I observed many negotiations for sharing limited resources. Resolving these issues takes a lot of time and talking, but wouldn't happen otherwise.

Flexibility and Commitment to Lifelong Learning I met a few engineers who had had the same job for a long time but many more who had switched jobs several times. Engineers have to adapt to frequent organizational changes and technology changes. Those who deal well with change and are willing to learn new skills are the most successful.

Problem Solving Skills Making airplanes is a complicated process that poses many engineering problems. For example, one of the tooling plants has a high-speed machine that is not running at its maximum capability. Determining how to better utilize that machine is a complicated problem involving understanding of machine design, operating conditions, and current machinists' practice. Talking with the machine manufacturer and other Boeing users of high-speed machines will help in selecting appropriate tool holders and cutters. Some testing and analysis will help in selecting optimum operating conditions. However, the biggest challenge is to convince the CNC programmers and machinists to follow your recommendations. A comment I heard several times related to problem solving is that many engineers often do not use common sense. Perhaps universities can teach that or give students more opportunities to develop it.

Seeing the Big Picture This hit home for me when spending time with the 757-300 leading edge integrated product development team. The -300 is a derivative of a production version. The task of this team is to modify the leading edge design to account for the higher loads that this plane will experience. They are not allowed to make design improvements. I sat in on a practice run for a critical design review in which engineers explained their modifications and reasons for them. They tended to want to point out collateral improvements (like easier manufacturability) that came along with redesigning for higher loads, but their supervisor instructed them to focus only on the higher loads. I empathized with the presenting engineers, but later several people explained to me how engineers love to engineer and that some improvements never pay for themselves.

The job tasks at a large company like Boeing are very specialized. For example, the function of manufacturing engineer is subdivided into 5 or 6 different jobs. Everyone's work is interrelated with everyone else's. "Seeing the big picture" helps all the separate parts work together to achieve a common goal.

Grounding in Traditional Manufacturing Processes This may be particularly true for design engineers. The responsibility for manufacturability is increasingly on the design engineer. Many see it as an additional burden--one more parameter/constraint. For engineers in the manufacturing facilities, this grounding seemed to improve confidence and chance of success. Several successful engineers commented that the engineers who were expecting to sit at a desk usually didn't last.

Understanding the Design Process One of the summer student interns from Tool Engineering stressed this. His university had given him some training on the steps in the design process and how to conduct team meetings. He felt that some of the meetings he attended at Boeing could have been more productive if everyone had that type of training.

Engineering Drawing This skill is particularly important for design engineers and producibility engineers. Beyond seeing the drawing, an understanding of geometric dimensioning and tolerancing (little emphasis at MTU) is very important. Our students do not spend a lot of time working with drawings during their 4-5 years here, which was surprising to some of the engineers I talked with. On the other hand, I met a design engineer who had no drawing or graphics classes in college and who was able to learn this skill fairly quickly.

Project Planning and Management The design build team manager emphasized this skill. Designers work on long lasting projects (1-3 years) and have to meet many deadlines along the way. New engineers are not good at planning.

Ability to Question and Analyze I didn't hear this one first hand too often and perhaps it is my own bias. During my visit I was exposed to several initiatives that started out simply as good ideas such as determinant assembly and lean manufacturing. Convincing others that these are good ideas requires salesmanship and analysis. Universities train engineers in the analysis part. In the case of determinant assembly, at one time some team of engineers looked at tolerance stack-up and manufacturing capabilities and showed that this was a better way. There have probably been many ideas that sounded good but which on further analysis engineers proved would not work. There have probably also been times when new ideas were implemented but shouldn't have been. And some ideas probably get analyzed to death at great expense (see the skill Seeing the Big Picture).

Current Curriculum Strengths

I was pleased to discover that universities do provide valuable training. After I questioned one of his ideas, one supervisor told me, "You might be real smart but I've got a lot of experience in these sorts of things." That shut me up but it shouldn't have. Without question there's no substitute for experience. However, smarts and experience can complement each other. University preparation aims to teach graduating engineers to question why and think about issues in depth. They demonstrate that an idea is good or bad by proving it.

My visit was heavily biased toward manufacturing activities as opposed to design activities. The need for manufacturing process and system concepts in the engineering curriculum was therefore evident. While MTU does not have a strong manufacturing engineering degree program (less than 10 students in the program), it does have a large number of courses in manufacturing (about 20). In addition, it requires mechanical engineering juniors to take a manufacturing processes class. We also have strong manufacturing research programs, which have tended to focus on automotive manufacturing.

Student organizations at MTU have given many students the opportunity to work on hands-on projects, for example SAE car projects. Recently, design project courses have become a required part of the curriculum. MTU should and can readily build upon these strengths.

Suggestions for Curriculum Improvement

The curriculum at MTU does not address many of the skills listed above. Mandatory design project courses will help. These should go a step further and include manufacture of a prototype. Most engineering jobs won't give new hires such hands-on experiences as operating a milling machine, yet they may need to know what one can do. School may be the only time they can gain that experience. A large number of our engineering graduates will be working in manufacturing environments. Design engineers, who may not be located at manufacturing sites, are becoming increasingly responsible for manufacturability.

Often people say that what you learn in college is not so important as learning how to learn. Learning is a process skill as are problem solving and teamwork. MTU curricula should teach them explicitly rather than assume students become good learners or problem solvers by doing a lot of statics and heat transfer homework. To make time for teaching these, I would suggest focusing on the basics in engineering science classes and letting the project courses motivate independent study of more sophisticated engineering science topics.

Many of the skills listed above are necessary to help students find their way in a large complex company like Boeing that makes large complex products. Some exposure to systems engineering would also help. Courses that include organizational behavior and lean manufacturing concepts would also be helpful.

Impact at MTU

Since returning to MTU I have shared my internship experience with my departmental colleagues and the College of Engineering's Industrial Advisory Board. I have also joined my department's curriculum committee. Besides implementation and assessment of the new senior design project course sequence and preparation for ABET accreditation, one of this year's committee goals is to brainstorm ideas on a complete redesign of the mechanical engineering curriculum.

The internship has made an impact on my teaching. I have shared new examples of industry practice in courses such as *Introduction to Manufacturing*, *Tool Design*, and *Metrology and Computer Aided Inspection*. For example, I've discussed lean manufacturing, set-up time reduction, the importance of CMM inspection cycle time, and use of tracking interferometers to qualify tools. In *Tool Design* I have put more real tool drawings in students' hands. In all my courses I've increased the emphasis on team projects and making presentations. The internship experience has helped me convince students that these are worthwhile activities.

Suggestions for Increasing Impact

One criticism of the internship is that I spent much of the month in a passive observing mode.

Just as active learning improves the impact of courses, it would also improve the impact of an internship. Making a short internship a more active experience will be challenging and take a lot of preparation. Other suggestions for improving the internship include narrowing the scope by setting one or two specific goals. Sending multiple interns to the same company could improve the chances of achieving change back at MTU. A goal for that group could be to develop a plan for a curriculum revision. Another type of goal is to develop materials for a course on a timely industry topic such as lean manufacturing.

Senior design projects have the potential to increase university/industry interaction. An internship goal could be to set up (perhaps even begin work on) a student design project. One of the managers mentioned that when universities contact his department for design project ideas, it is difficult to come up with suitable ones. Faculty interns can help with this because they have a better sense of what is suitable for student teams. Many student design project ideas came to light during my tour of MR&D facilities.

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Biography

MICHELE MILLER received her Ph.D. in Mechanical Engineering in 1994 from North Carolina State University. She has worked for General Motors as a manufacturing engineer and, since 1994, has been an Assistant Professor at Michigan Tech. Her research interests include the precision machining of ceramics and the control of machine tools. She serves on the Board of Directors of the American Society for Precision Engineering.