Session 3649

Introducing Hands-on Manufacturing Experience to Students

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Abstract

This paper describes a laboratory-based course in Manufacturing Processes that provides hands-on manufacturing experience to students in Engineering Technology. The theoretical part of the course provides a general understanding of the behavior of the materials commonly used in manufacturing, the basic techniques used in processing them into useful products, the scientific theory underlying those processes, and the criteria for selecting particular processes. The laboratory portion involves team projects that help students gain hands-on experience with selected manufacturing processes. The projects start with simple components that can be made on a single machine such as a lathe or a mill, and progress to the manufacture and assembly of a fully operational model engine. This approach introduces students to the issues involved in putting together a non-trivial assembly. The projects also expose students to the idea of working in teams, a skill that is highly sought by industry.

Introduction

The high cost of setting up a state-of-the-art manufacturing facility means that universities usually have to make difficult choices about the resources they dedicate to courses in manufacturing. Consequently, many university courses in manufacturing processes or related subjects are skewed towards theoretical concepts and offer limited hands-on experience for the students (if any). Frequently, students' exposure to actual processes is limited to observing demonstrations by the instructor, or simply watching video tapes, but with the students not getting their hands on the equipment. There is also the possibility of using simulations but these are still primarily in the research stage and they do not yet offer sufficient realism[1].

Another way to overcome these constraints is to arrange for cooperative experiences that allow students to work in a manufacturing facility as part of their degree program[2,3]. This requires extra commitment from the students, since it normally entails at least one semester away from school. Moreover, it can be challenging to find appropriate placements for all students participating in the program.

Wayne State University (WSU) is subject to the same economic pressures as other universities. Nevertheless, the author has developed an innovative course - MIT 3510 Manufacturing

Processes, that covers a wide range of processes, while still affording the students an opportunity to gain substantial practical experience with selected processes. The course requires five contact hours a week, divided into two 2.5 hours sessions per week over a 15-week semester. One session is for lectures while the other session is spent in the laboratory. The course is worth 3 semester credits. The course's topical coverage is shown in Table 1:

Table 1: Outline of the Manufacturing Processes Course

Introduction to Manufacturing:	Manufacturing and its economic role. Standardization and interchangeability of mass produced parts. (2 weeks)
Properties of Engineering Materials:	The nature and engineering properties of common materials and how these influence manufacturing processes. Review of deformation of materials, the importance of the stress-strain curve, and implications for manufacturing. (2 weeks).
Production of Engineering Materials:	The extraction of common engineering materials from their naturally occurring forms. (2 weeks).
Casting Processes:	Definition of casting and detailed description of the sand casting process. Discussion of the requirements and limitations of casting processes in general. Survey of widely used casting processes and comparison of their capabilities. (2 weeks).
Machining Processes:	Definition and mechanics of machining. Sample machining processes. Determination of cutting conditions. Cutting tool materials and geometry, tool life, and cutting fluids. (2 weeks).
Welding Processes:	Definition of welding, weld metallurgy, weld defects. Description of common welding processes, comparison of capabilities of the various processes (2 weeks).
Forming Processes:	Description of sample forming processes. Discussion of process requirements, capabilities, and limitations (2 weeks).

It is generally not feasible for any university to develop laboratories encompassing all of the different processes covered in a course like this. A choice has to be made as to the processes that will be supported and WSU’s Machine Tools Laboratory is equipped to support the traditional machining processes such as turning, milling, grinding and welding. Until three years ago, the time available in the laboratory was used to make several small discrete parts that demonstrated the traditional processes like milling and drilling. Students themselves did the machining and therefore obtained hands-on experience in the pertinent processes.

Whereas the students were able to gain experience with the processes using this approach, it was felt that more could be done to make the laboratory experiences both more challenging and interesting for the students. To accomplish this, the author decided to change the nature of the projects that students have to undertake in the laboratory. Specifically, the series of simplistic, unrelated and non-functional components were eliminated and it was decided to incorporate a major project instead. (An example of such a simple component is shown in Figure 1.) The project that was settled on was the making of a model engine that students could test at the end of the semester. Using a major project of this nature offers many advantages to the students. Not only do they get exposed to the same processes they encountered in the original setting, but now they also get to assemble the engine they make and watch it in operation. Having a functional product at the end of the semester is inherently motivating to the students and affords them a valuable sense of accomplishment.

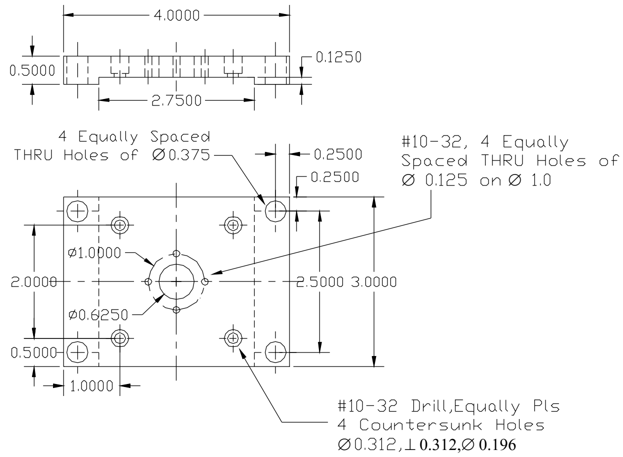

FIGURE 1: INTRODUCTORY MILL PROJECT

2. Overview of The Learning Factory Model

The Learning Factory concept was developed jointly by Pennsylvania State University (PSU), University of Washington (UW), and University of Puerto Rico-Mayaguez (UPR-M) in collaboration with Sandia National Laboratories. These were the lead institutions in the Manufacturing Engineering Education Partnership (MEEP), funded by the Technology Reinvestment Program and the National Science Foundation. The Learning Factory concept was developed as both a new kind of curriculum, and an integrated manufacturing facility. It integrates a practice-based curriculum with physical facilities for product realization in an industrial-like setting[5]. The specific objectives of this project were to develop:

(1) A practice-based engineering curriculum which balances analytical and theoretical knowledge with manufacturing, design, business realities, and professional skills;
(2) Learning Factories at each partner institution, integrally coupled to the curriculum, for hands-on experience in design, manufacturing, and product realization;
(3) Strong collaboration with industry;
(4) Outreach to other academic institutions, government and industry.

The Learning Factory offers students in traditional engineering disciplines an alternative path to a degree that directly prepares them for careers in manufacturing, design and product realization. Its approach to manufacturing engineering education provides balance between engineering science and engineering practice, with opportunities for application and hands-on experience. Students who choose this program begin working in the Learning Factory in the first year as a direct component of their coursework and this expands in scope as they progress through their academic career. Students work in interdisciplinary teams and collaborate on industrial projects, experiencing the total process of product realization from conceptual design through prototyping, marketing, production, quality improvement and ultimate disposal. This approach develops in students the essential skills of teamwork, communication, project management, and problem solving [6,7].

The Learning Factory concept was implemented at each of the three originating schools as a 3500 ft^2 facility at PSU, a 4000 ft^2 facility at UPR-M, and a 6500 ft^2 facility at UW. Four new courses were developed and shared across the partnership namely: Product Dissection, Concurrent Engineering, Technology Based Entrepreneurship, Process Quality Engineering, and Interdisciplinary Design Project. The new courses were built around a core of existing courses namely: Graphics, Design, and Manufacturing Processes; which were modified to take advantage of the new facilities made possible by the Learning Factory. The courses have been arranged into a 15 credit Certificate in Manufacturing at UPR-M, a 24 credit Product Realization Minor at PSU, and a 22-26 credit Product Realization Option at UW[7]. The implementations also involve partnerships with local industries at each institution, with industry contributing funds, time, equipment, and ideas for senior design projects.

3. Prototype Implementation of the Learning Factory Model

The incorporation of the making of a model engine in WSU's Manufacturing Processes course could be considered a prototype implementation of The Learning Factory Model. The specific approach taken was to change the type of projects that students have to do in the laboratory. Starting in Fall 1998, the previous series of simple, unrelated and non-functional components were replaced with a major project instead. Figure 2 shows a 'Pip-Squeak Engine', an example of one of the engines fabricated by the students. Other engines that have been made as part of the course include the Stirling Engine, and the Two-Poster Engine.

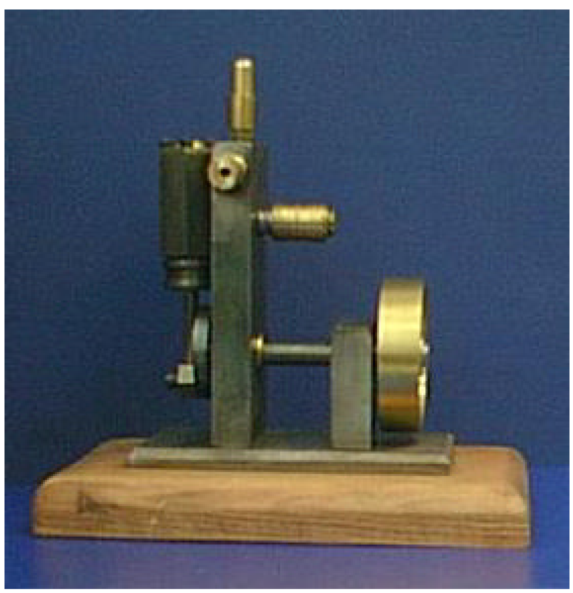

FIGURE 2: A FINISHED 'PIP-SQUEAK' MODEL ENGINE

Experience gained with these engines has shown that having a functional product at the end of the semester is inherently motivating to the students and affords them a sense of accomplishment that is extremely satisfying to both the instructor and the students. In particular, seeing their model engines in operation is a thrill to the students. There are several different model engines to choose from, allowing variation in the specific model that is made from semester to semester[8].

Because making a model engine is quite a challenging project, two of the simpler components that students used to make before the introduction of the new approach were retained. One component is used to familiarize students with the operation of a lathe, while the other is used to familiarize them with the operation of a mill. The students work on these simple projects first, before embarking on the making of the engine. Within the course, students are first introduced to general shop practices and important safety procedures. The introductory lathe exercise introduces students to the use of a cutoff-saw, grinding of cutting tools, and the basic machining processes used on a lathe. The introductory mill exercise introduces students to milling and drilling type processes. The component used to introduce milling type processes was shown in Figure 1. For the major project, students will go through the complete process of making a model engine in line with the requirements given on standard shop drawings. This requires the use of both a lathe and a milling machine. Figure 3 shows examples of WSU students working at some of the machines during the laboratory.

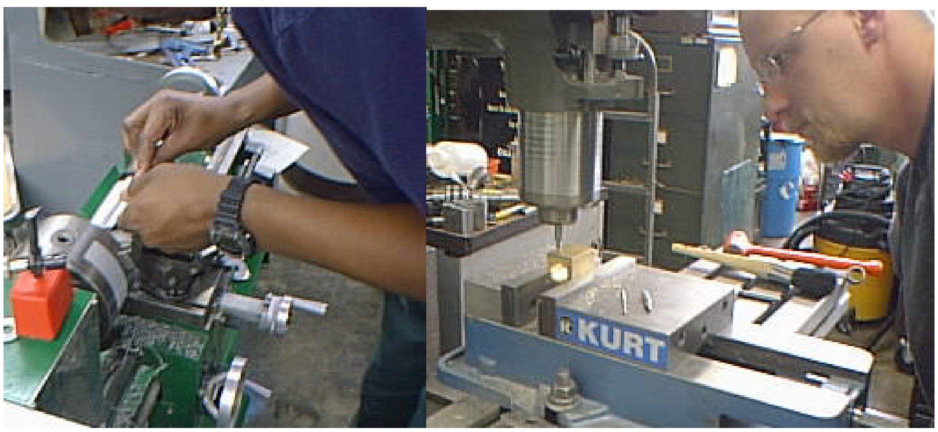

FIGURE 3: HANDS-ON EXPERIENCES FOR THE STUDENTS

Although developed independently, it turns out that this approach is similar to that described by Weller et al at University of Washington[4]. WSU's implementation differs from that at UW in some important respects however. UW follows a quarter system while WSU has a semester system. This means that at UW, each project has to be completed within 10 weeks as opposed to the 15 weeks available for WSU students. The laboratory sections at UW include an average of 10 students, and the instructor assigns specific components (usually 3) to individual students at the beginning of the quarter, which are then brought together when the engine is ready for assembly. At WSU, the groups typically have 3-5 students and they have to work as a cohesive team in making the complete engine, and assignment of individual duties within the team is the responsibility of the students themselves, not the instructor. In practice, the WSU students on average work on twice as many components as the UW students. Thus there is much greater focus on the hands-on machining for WSU students. On the other hand, UW students can get into more theoretical issues like process planning that the WSU students do not cover in this course. Instead, WSU has a completely independent course in Process Engineering. This difference in emphasis can in part be attributed to the fact that the UW course is intended for Mechanical

Engineering students while the WSU course is intended for Engineering Technology students. One other difference is that UW has incorporated non-machining processes such as casting and injection molding, while the focus at WSU is strictly on machining processes.

In addition to gaining hands-on experience, WSU's Manufacturing Processes course is also used to develop students' skills in written communication which is one of the ABET accreditation requirements. To accomplish this, students are required to write a detailed laboratory report for each of the projects they undertake. Detailed report guidelines have been developed and are given to the students at the beginning of the semester. The same basic outline is followed for all projects. For the model engine project, the instructions call for the inclusion of a complete bill of materials, identification of processed parts and a description of how they are made, clearly distinguishing them from off- the-shelf items such as screws; and a description of the engine assembly and testing procedure. In grading the laboratory work, the quality of parts made, as well as the quality of the written report (including spelling and grammar), are taken into account.

4. Discussion

A number of implementation issues arose with the use of project teams and these are instructive for all implementations of cooperative learning. It is a temptation for some students to not participate fully in the work of the group. In such instances the problem is that students can get credit for work to which they have not contributed. This is not only unfair to those group members who end up doing the bulk of the work, but it is also detrimental to the lax students themselves since they don't get to comprehend the material as fully as they otherwise might have.

The author has instituted several policies to address this problem. In the first instance, the group members are called upon to police themselves. Before a group assignment is turned in by the students, they are instructed that only the names of people who have actually contributed to that particular assignment be included on the assignment. Also, students are required to specify in the report, the role played by each individual for that particular project. In other words, one is not entitled to group credit simply by virtue of membership in the group. This simple step has helped to alleviate problems on a number of occasions. When a student indeed did not contribute to an assignment, they have graciously accepted that they do not get credit. This also appeases the hardworking students because it eliminates free-loading. Secondly, a significant portion of the final grade (30%) has been allocated to the performance on the laboratory projects. This helps to ensure that the students indeed take these assignments seriously. Due to this significant weighting, anyone not participating in the group work is practically guaranteed to fail the course. This builds in a major incentive to contribute to the group.

The experience gained with this course has been very positive and students have also reacted very favorably to the new approach. In particular, seeing their model engines in operation is a thrill to the students. The only problem has been with how to decide who gets to keep the finished product since there was one engine between 3-4 students! The success experienced with this course has encouraged us to apply the approach to other courses and the concept is in the process of being implemented in three other related courses, namely: Computer Graphics, Process Engineering, and Computer Aided Manufacturing and Design.

6. Conclusion

The Manufacturing Processes course described in this paper not only covers theoretical aspects of manufacturing such as the basic processing techniques and the scientific theory underlying those processes, but also includes challenging team-based laboratory projects that help students gain experience with selected manufacturing processes. The projects start with making simple components and progress to the manufacture and assembly of a fully operational model engine. The course provides students with hands-on manufacturing experience within a university setting. The projects also expose students to the idea of working in teams, a skill that is highly sought by industry. The course has been received very enthusiastically by the students.

Acknowledgments

The author gratefully acknowledges the work of the laboratory technician, Mr. Larry Herrick. His dedication and commitment helped to ensure the smooth running of the projects.

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Biographical Sketch

Dr. Ssemakula graduated from the University of Manchester Institute of Science and Technology, UK, with a Ph.D. in Mechanical Engineering in 1984. He joined the Wayne State University in 1993 and is currently teaching courses in Manufacturing/Industrial Engineering Technology. His has research interests and has published widely in the areas of Manufacturing Systems and Computer Aided/Distance Education.