AC 2008-1700: OUTCOMES ASSESSMENT IN A HANDS-ON MANUFACTURING PROCESSES COURSE

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Outcomes Assessment in a Hands-On Manufacturing Processes Course

Abstract

Industry has consistently identified lack of experience in manufacturing processes as one of the key competency gaps among new engineering graduates. This paper will discuss a laboratory-based Manufacturing Processes course that provides hands-on manufacturing experience to students. In addition to standard theoretical concepts, the course uses team-based 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 functional mechanism. This approach introduces students to the issues involved in putting together a non-trivial assembly. Multiple evaluation tools including surveys, focus-groups, and actual observations, were used to determine the effectiveness of the approach used. The results indicate that this is an effective way of addressing industry concerns.

1. Introduction

Educational research has shown that students' approach to learning is characterized by different learning styles, while instructors have their own corresponding teaching styles[1,2]. Students whose learning styles are compatible with the instructor's teaching style tend to retain information longer, apply it more effectively, and have more positive post-course attitudes toward the subject. Various learning style models have been developed, the four most well known being: *Myers-Briggs Type Indicator* (MBTI), *Kolb's Learning Style Model* (KLSM), *Herrman Brain Dominance Instrument* (HBDI), *and Felder-Silverman Learning Style Model* (FSLSM). The FSLSM model is particularly suited to engineering education[2]. It classifies student learning styles as shown in Table 1.

Table 1: Felder-Silverman Learning Style Inventory

sensing learners (concrete, practical, oriented toward facts and procedures)	vs.	*intuitive learners* (conceptual, innovative, like theories and meanings);
visual learners (like visual presentation: --pictures, diagrams, flow charts)	vs.	*verbal learners* (prefer written and spoken explanations);
inductive learners (prefer presentations proceeding from specific to general)	vs.	*deductive learners* (prefer presentations that go from general to specific);
active learners (learn by trying things out, working with others)	vs.	*reflective learners* (learn by thinking things through, working alone);
global learners (holistic, systems thinkers, learn in large leaps).	vs.	*sequential learners* (linear, orderly, learn in small incremental steps)

Traditional engineering instruction favors intuitive, verbal, deductive, reflective, and sequential learners, even though most engineering students tend to fall in the opposite categories. To improve overall student learning and meet industry expectations, it is important to develop educational materials that address the needs of students outside of the favored categories. Another key motivation is that companies are also focusing more on recruiting new graduates who have the experience to make a quick contribution to corporate goals. Competency in a range of skills related to product development is expected from engineering and technology graduates.

In 1997, the Society of Manufacturing Engineers (SME) launched its Manufacturing Education Plan (MEP) to address key engineering competency gaps of new graduates that it had identified[3]. The gaps identified in 1997 were revised in 1999 and revised further in 2002-03. The latest rankings are shown in Table 2. (Note: higher ranking indicates larger competency gap and greater need.) Since the institution of the MEP, SME has funded more than $15 million for diverse projects across the country to expand and improve manufacturing, engineering, science, and technology education so as to help close these competency gaps.

Table 2. Ranked SME Competency Gaps

1. Business knowledge/skills
2. Supply chain management
3. Project management
4. International perspective
5. Materials
6. Manufacturing process control
7. Written & oral communication
8. Product/process design
9. Quality
10. Specific manufacturing processes
11. Manufacturing systems
12. Problem solving
13. Teamwork/working effectively with others
14. Personal Attributes
15. Engineering fundamentals

This paper discusses a Manufacturing Processes course deigned to address these issues by providing practical hands-on experiences that encourage students to ‘learn by doing’.

2. Background

In 1994, NSF awarded the Manufacturing Engineering Education Partnership a grant to develop a novel program focused on product realization/manufacturing engineering. This partnership created and institutionalized the Learning Factory (LF) concept, focused on hands-on, practice based engineering, continuous assessment and industry collaboration[4,5]. The original Learning Factory concept was implemented at each of the three originating schools as a 325 m^2 facility at Pennsylvania State University, a 370 m^2 facility at University of Puerto Rico-Mayaguez, and a 600 m^2 facility at University of Washington. The objective was to create an integrated practice-based engineering curriculum that balances analytical and theoretical knowledge with physical facilities for product realization in an industrial-like setting. The LF model offers students in traditional engineering disciplines an alternative path to a degree that prepares them for careers in manufacturing, design and product realization.

Although the LF model has been successfully implemented in several other universities, full implementation can be expensive. In 2002, Wayne State University was awarded an NSF grant to develop an adaptation of the LF model that would be less costly to implement. Our NSF project involved the adaptation the original LF model for implementation in a laboratory setting[6,7]. This was accomplished by introducing the use of coordinated hands-on projects in standard laboratory settings across selected courses, using a model engine as the unifying theme. This is a more cost-effective way to give students hands-on experience in a range of issues involved in product realization while giving students hands-on experience in specific manufacturing processes including assembly. A functional product is inherently motivating to the students and affords a sense of accomplishment and satisfaction. The adaptation was implemented through the modification of the four courses shown in Table 3.

Table 3: Targeted Courses for Development Activities.

Course	**Description**	**Revised Engine-Related Activities**
ET2140 Computer Graphics	Solution of drafting problems and development of graphic presentations using CAD	Generate fully dimensioned CAD drawings of select engine components and assembly drawings of complete model engine, including bill of materials.
MIT3510 Manufacturing Processes	Study of selected manufacturing processes; Fabrication of materials using conventional machines; Calibration and setup	Make the engine components using conventional machine tools. Instructor gives informal guidance on process planning issues. Assemble and test engine. Write detailed report describing the manufacturing and assembly process.
MIT3600 Process Engineering	Manufacturing analysis. Selection of machining parameters, tooling, and equipment. Process planning.	Generate formal process plans for fabricating the engine components using NC machines, including determination of all machining parameters. Also generate the assembly plan.
MIT4700 Computer Aided Design and Manufacturing	Fundamentals of computer-aided manufacturing. CNC, 2-d and 3-d applications programming	Based on MIT 3600 process plans, develop NC programs to make engine components. Verify and troubleshoot NC programs. Produce engine components on NC machines. Assemble and test engine. Write detailed report describing the manufacture and assembly processes.

Each of the courses incorporates hands-on experiences in the form of either laboratories or projects. The critical part of the adaptation was the careful coordination of those hands-on experiences in multiple courses around the unifying theme of the making of a model mechanism. Students start in the Computer Graphics course (ET2140) by generating drawings of the various components of the engine. These drawings are then used in subsequent courses. For example, the drawings form the blueprints used in the Manufacturing Processes course (MIT3510) as well as the Process Engineering course (MIT3600). The process plans are then used in the Computer Aided Design and Manufacturing course (MIT4700). Figure 1 shows a model engine made according to this procedure. The rest of this paper discusses how outcomes assessment was conducted to determine if the courses were meeting their intended objectives with the discussion concentrates on the Manufacturing Processes course.

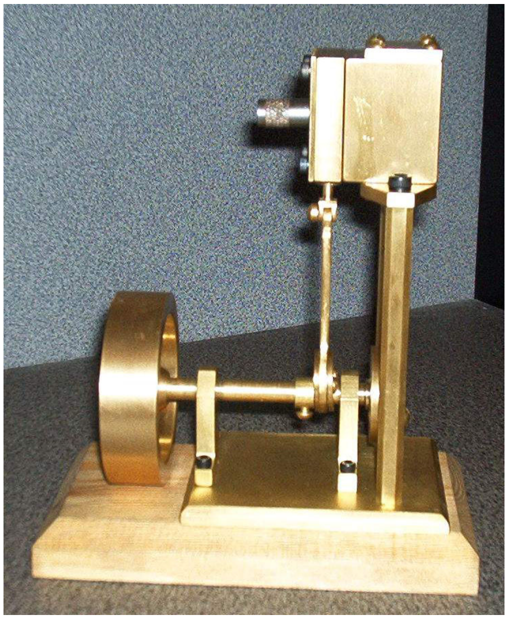

Figure 1: Finished “2-Poster” Model Engine

3 Targeted Learning Outcomes

The Manufacturing Processes course (MIT 3510) is a required course in our Mechanical Engineering Technology (MCT) curriculum. We have developed detailed descriptions of expected learning outcomes at both the program level and the course level and the assessment described in this paper is to help us ensure that we are meeting those outcomes. Table 4 shows the course level learning outcomes, while Table 5 shows the program level learning outcomes and how the Manufacturing Processes course helps to meet those outcomes. These constitute a core body of knowledge that helps to meet industry-identified competency gaps.

Table 4: Core Course-Level Learning Outcomes

1. Distinguish between design and manufacturing, and the relationship between them.
2. Specify fit and tolerance of standardized and/or interchangeable mating parts.
3. Use preferred numbers in selection of sizes
4. Describe how the internal structure of metals impacts properties and processing.
5. Describe how at least 2 common engineering materials are extracted from their ores
6. Describe selected manufacturing processes, including their capabilities and limits.
7. Select appropriate machining processes and tools to make a given part
8. Describe safety procedures that need to be followed in a machine shop
9. Identify and operate a lathe, drilling, and milling machines
10. Determine the important operating parameters for each of these machines
11. Use standard shop gages to inspect parts
12. Effective oral and written communication.
13. Work successfully as a member of a team.

Table 5: Course Contribution to Program Learning Outcomes

Contribute	MCT Program Level Outcomes
	1 A firm foundation in mathematics and sciences required for understanding, application, and development of mechanical engineering technology principles
	2 Technical expertise in engineering materials, statics, dynamics, strength of materials, fluid mechanics, thermodynamics, and instrumentations electronics
√	3 Technical expertise having added technical depth in manufacturing processes, mechanical design, fluids and thermal sciences
√	4 An appropriate mastery of techniques, skills and modern tools for mechanical engineering technology
√	5 The ability to communicate effectively in oral, written, visual, and graphical modes in both interpersonal and group environments
√	6 the attitudes, abilities, and skills required to adapt to rapidly changing technologies and the ability to pursue life-long learning
√	7 An understanding of all aspects of the design process and project management including functional and esthetic considerations
	8 A well-developed sense of ethics, global issues, professional and social responsibility, and a respect for diversity
√	9 The skills and attitudes necessary to work successfully as a member of a team

4. Outcomes Assessment Surveys

Because the Manufacturing Processes course (MIT 3510) is the course in which students get to use the machines to fabricate the engine components and assemble the engine, it was decided to use this as the centerpiece of the assessment efforts as it offers the greatest opportunity to encounter the project goals. Outcomes Assessment was conducted at two distinct levels. One involved standard end-of-semester student course evaluation while the other involved interactive focus group interviews.

An external evaluator was engaged to conduct the focus group interviews with students in the course. Interviews provide a mechanism for capturing information that may be difficult to observe or that may not show up in a traditional survey. Focus groups are a special type of interview that takes place within a group context rather than one person at a time. Interpersonal interactions in a focus group often lead to more detailed responses than would be possible otherwise[8]. In our case, the interviews were conducted close to the end of the semester when students had had ample opportunity to experience the important course activities and thus could comment on whether course intent was being met. Using an external evaluator ensured anonymity for the participants.

During the focus group interview, students were asked to respond to a set of questions and to indicate whether there was consensus on the response or if the group was split, to provide an indication of the range of responses. Sub-group responses were shared with the larger group and then collected. All the responses gathered were anonymous. Responses for each question are provided below. It is important to keep in mind that responses were gathered without comment by the interviewer. The responses are the students' perceptions which provide an important perspective, but may not reflect an understanding of the constraints or goals existing in the class environment. The interviewer did not offer any correction or explanation of points that students brought up as the purpose was only to gather perspective.

Table 4: Questions for Focus Group Interview

Question 1: *To what degree has this lab course led you to a better understanding of what it means to make a part? Do you feel that there was enough time allowed in the lab and the manufacturing experience was effective?*
Question 2: *To what degree has this course helped you to understand what happens at the manufacturing level, both as regards processes and part design?*
Question 3: *To what degree has this class helped you to better understand the language that is used on the shop floor? Do you feel better prepared, as a result of this class, to interact with others involved in the technical processes covered here?*
Question 4: *How helpful has the lab manual been in your learning and in your ability to follow lab practices?*
Question 5: *Please evaluate the pace followed in this course: has this lab course moved too quickly, too slowly, or has it been just right?*
Question 6: *Have the assignments and activities in this class facilitated your learning and understanding?*
Question 7: *If you could change this course, what are the top 3 things that you would change to increase your learning? If this course were to be changed, what would you say should not be changed at all because to change it would be to weaken your learning?*

A1 Students agreed that the hands-on laboratory experience was very helpful for learning how to use the machines. Overall, the students felt that they gained comfort with basic machining operations, the skills and attitudes necessary to work as a member of a manufacturing team, but they would like more time with the machines.

A2 Students agreed that the laboratory experience has provided a feel for what happens at the manufacturing level but there was disagreement about the *degree* to which this was true. Overall, the students felt that they learned a lot about the basic essentials of manufacturing processes. They feel very comfortable with the machines that they worked on and that they would be able to explain to others how they work.

A3 Most students agreed that they feel much more comfortable with the language of the shop floor and they agree that this is important to know. They learned new terms, sizes, names, and machines and said that they definitely benefited from interacting with each other and with the lab technician.

A4 Students agreed that the laboratory manual served as a good reference, especially for writing the lab reports. It was easy to use, well laid-out, and the descriptions were clear and helpful. They agreed that it will be a good reference to have in the future.

A5 All students agreed that the pace of the lab class is too fast. The students did not feel that there was time for two projects plus a final project. They suggested having open lab time available. They also felt that the pacing was uneven, with the first part of the semester moving too slowly and the last part of the semester moving much too quickly.

A6 Students agreed that the assignments and activities facilitated learning. They were very enthusiastic about the hands-on aspect of the course and that this exposed them to many things that helped them to understand manufacturing. The only concern was the amount of time allowed for the activities. All agreed that learning would be improved if more time were allowed for the hands-on portion of the class.

A7 This is a standard question asked of focus groups to make sure that nothing important is missed. The top answer of all students in what not to change was the presence and necessity of the lab technician. All agreed that without the technician, this class would not be successful or even possible. They also all agreed that the hands-on experience is the most valuable aspect of the class. Suggestions include:

- Smaller class size.
- More set up time
- More lab time
- More modern tools/machines
- Expand class scope to increase exposure to each machine and to other processes.
- Ensure each person in a group gets the same amount of time on the machines
- *Do not* change lab technician

A more traditional Student Evaluation was also conducted in the form of an-end-of semester student survey in which students were asked to rate if they agreed that they had achieved the specified course outcomes. The outcomes in this case are listed in Table 3. Students indicated their response by selecting from five options: Strongly Agree (SA), Agree (A) No Opinion (NO), Disagree (DA) or Strongly Disagree (SD). The results for SA and A were subsequently aggregated under YES and the results for DA or SD were aggregated under NOT; to indicate whether each learning outcome had been met or not. A threshold score of 75% was set to indicate an acceptable level of performance.

The results indicated that the students met the desired level of performance in all the course outcomes except outcomes number 4 and 5. The results for outcomes 7 through 11 relating to hands on experiences (and the main focus of this work) were especially gratifying as they indicted complete student satisfaction with their course experiences. There was concern about outcomes 4 and 5 that fell below the threshold and especially for outcome 5 with 25% negative rating. Looking at student performance on tests and homework assignments indicated that students had a good understanding of these topics. It was decided not to make precipitous changes at this stage and wait for the results of the next survey to decide if in fact this was a real problem or just an anomaly. The issue did not show up in subsequent evaluations in later semesters leading to the conclusion that the initial concern was an anomaly.

5. Discussion

In light of the above assessment results and student feedback, our initial LF adaptation was modified. The modification was made to address two themes that clearly arose from the evaluations and feedback from focus groups, namely: to allow students more time to carry out the required machining tasks, and to expose students to additional manufacturing processes. With this in mind, the product made by the students was changed from a model engine to the model machine vise shown in Figure 2. The vise entails simpler machining work while still exposing students to the same types of hands-on operations. The simplified project can therefore be completed in less time and the balance of the time used to give students more hands-on experience of additional manufacturing.

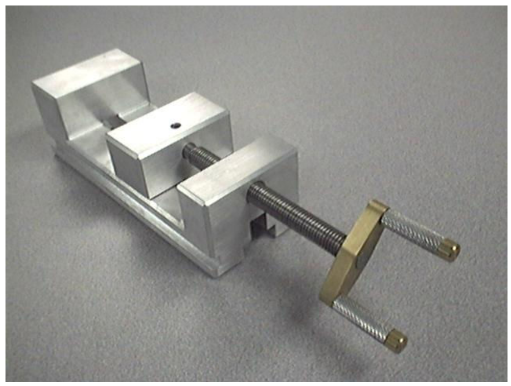

Figure 2: A Model Machine Vise

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