Revving up interest in Hands-On Engineering

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Introduction:

This paper provides an overview of the past, present, and future changes to a laboratory-based course providing hands-on experience in manufacturing. At the 2002 conference for the ASEE, Mukasa E. Ssemakula presented a paper (session 3649)[1], describing successes for a course that helped students gain hands-on experience in a Mechanical Engineering Technology (MET) program. Using this presentation as a springboard, a pilot program at Penn State Erie, the Behrend College, was developed which incorporated those methods and enhanced them.

Sophomore students in the (MET) program at Penn State Erie are required to take a hands-on lab, titled Production Design, intended to introduce the students to typical industrial processes. These processes include metal cutting (turning and milling), CNC machining, sheet metalworking, welding processes, and metal casting (aluminum). The lab meets twice each week for 3 hours per meeting over a 15-week semester. The total number of 30 lab meetings and a total lab time of approximately 90 hours is sufficient to complete the required tasks.

Past practice:

In previous years the entire lab was focused on a non-engineering approach to the processes. The lab was taught more as an operational or technical approach on the various processes, whereas the students were introduced to the various processes and taught the physical operations of each. This approach was used to familiarize the students with each processes advantages and disadvantages in the typical industrial manufacturing environment. For safety reasons the class size was restricted to 12 students, divided into 4 groups of 3 students each. There were a total of five modules within the course: Metal cutting (Milling & Lathe), CNC machining, Sheet Metalworking, Welding (& Joining), and Metal Casting (Foundry). Each group of 3 students was assigned to a different module to start with and they would work on the module for 3 weeks (6 lab periods) prior to proceeding onto the next module. The first lab session was reserved for the course overview and information of the safety issues within the lab environment.

Table 1.
Table of Past Laboratory Schedule

Labs sessions	Group 1	Group 2	Group 3	Group 4
1	**Safety**	**Safety**	**Safety**	**Safety**
2 - 7	*Milling & Lathe*	*Hand Tools & Sheet Metal*	*Welding & Joining*	*CNC Machining*
8 - 13	*CNC Machining*	*Milling & Lathe*	*Hand Tools & Sheet Metal*	*Foundry*
14 - 19	*Foundry*	*CNC Machining*	*Milling & Lathe*	*Welding & Joining*
20 - 25	*Welding & Joining*	*Foundry*	*CNC Machining*	*Hand Tools & Sheet Metal*
25 - 30	*Hand Tools & Sheet Metal*	*Welding & Joining*	*Foundry*	*Milling & Lathe*

The course used the same textbook (Degarmo)[2] as the lecture portion of the class in addition to both a machining practices book (Kibbe)[3] and a lab manual created at Penn state. The lab manual specifically detailed the student's assignment(s) within each module. Within each module, the students were required to read the appropriate textbook material (Degarmo and Kibbe) pertaining to the module they were assigned, complete the homework assignments, and familiarize themselves with the components for each machine. The lab instructor would then demonstrate the proper operation of the machines to each group of 3 students. Each module was performed by a group of 3 students during which they would each manufacture small pre-designed projects as a demonstration of their understanding of each process. This class was never intended to train students to be proficient at operating machines, only to introduce them to the basics operations and the minimum skills to perform them. In this way, the students would know the limitations of the processes and what manufacturing choices were available. During each of the modules, the students were required to complete and submit for grading a small project. Some examples of the small projects are as follows:

Milling/Turning:

Two separate projects were assigned for this combined module. For the milling portion, each student in the group fabricated an aluminum block using layout tooling, end mills, chamfering tools, and drills. For the turning operation, the students fabricated an aluminum bar with OD turning, grooving, chamfering, drilling, knurling, threading, and cutoff.

CNC machining:

The CNC mill used at the Behrend College has an *Accurite* software program to create tool paths. The program does not use the standard G-Code programming but rather a menu driven system. The student's objective is to create a pattern on a wooden block using linear lines, arcs, drill patterns, and text milling. When the students have completed the wooden block, they designed and fabricated a wooden casting pattern for use in the next module (Metal Casting).

Casting:

The method of casting used at the Behrend College is aluminum sand casting. The students started the module by practicing the making the a sand mold. This required that they properly mixed the sand, mulled the material, and applied the material to a standard pattern. When the pattern had been properly formed, the students would melt the aluminum and pour the metal into the mold, with the instructor's assistance. After the students had demonstrated that they could properly create a sand mold, each student then formed the mold from their respective patterns and poured the material.

Welding:

The welding processes covered during this course were MIG, TIG, ARC, Brazing, Oxy-Fuel, Spot welding, and Torch cutting. Each student practiced each of the welding processes and produced a sample of the best welds that they could produce for grading.

Sheet Metal:

During the sheet metal modules, the students must properly calculate bend allowances and layout the material for shearing and bending. The goal is to produce a finish open top box to the proper dimensions. The students would also produce a metal drill gage using metal punches, shear, and files.

At the end of each module, the students were required to write a complete report on the module's various processes. By the end of the term, each student had written a total of 5 large reports and approximately 200 homework questions. The university uses an assessment system for student satisfaction called Student Rating of Teaching Effectiveness (SRTE) in which the class students rate both the course material and the instructor. The averages for both the course and the instructor have been 5.5 out of a possible 7.0 or about a 79% satisfaction.

<u>Present Practice:</u>

During the spring of 2003, a pilot program was introduced for this lab, which was intended to enmesh more of the applied engineering concepts of the processes into the process itself. In groups of 3, the student's were required to reverse engineer an existing design (a small pneumatic engine) and manufacture a replica with all of the engineering and manufacturing requirements necessary to produce the assembly. The engine, called a Pip-Squeak engine[4], is a single cycle air driven unit with 12 manufacturable components. The plans are available on-line at Nimcoinc.com for a low cost. The original plans were simplified in order to reduce the number of components to 12. This was done to allow sufficient time to manufacture all of the parts necessary for the assembly. Since the intent of this pilot program was to introduce more manufacturing engineering to the students, the first step included reverse engineering the unit by disassembly, inspection, and documentation. The next steps were to create CAD component drawings with proper dimensioning and tolerancing, assembly drawings, and a complete bill of material. In addition, the students were required to produce manufacturing instructions (routing/planning) for each component, which included step-by-step instructions, tooling needs, and process parameters (feeds, speeds, etc). When all of these items were complete and satisfactory to the instructor, the students would then fabricate the parts to their own specifications and assemble. During this entire process the students were introduced, via hands-on operations and practice, to each of the processes mentioned in the past practice above with the exception of the 5 reports, which were omitted.

The engine project guidelines given to the students, in writing, are as follows:

Each session group of 2-3 students is to perform the following tasks

1. Design
    a. Reverse Engineering
        i. Disassemble the engine unit to base components, remembering how to reassemble.
        ii. Measure each component to 3 decimal places
        iii. Identify the material for each component
    b. Functional Design
        i. Create a Bill Of Materials (BOM)
        ii. Create component Drawings (Pro-e) and Assembly drawings with *dimensions and tolerances. Choose the appropriate tolerance for the application!*
    c. Create the manufacturing plans (detailed steps, machine setup, speeds, feeds, DOC, tooling, etc)
    d. Create the inspection procedures (Drawing dimensions vs. Actual dimensions)
    e. Approval (You must have approval of your design prior to manufacturing.)
2. Manufacturing

    As a group, manufacture each component as time permits. Common items such as springs, nuts, screws, bolts will be provided. Any deviation from the manufacturing plan must be documented and explained within the final report. When all of the components are fabricated, assemble and test the unit.
3. Testing

    Each unit will be tested for functionality and inspected for quality (dimensional accuracy)

In order to allow for the time to complete the engine model, some of the previous class requirements had to be relaxed. Safety could never be relaxed nor under emphasized to the students. Each of the modules was shortened slightly (5 lab meetings each module) by eliminating the requirement for individual process reports and shortening some of the requirements in two of the modules as follows.

CNC Milling:

The module group (3 students) design and fabricate one casting pattern instead of 3 patterns. The group pattern must be a unique design for the base of the engine project. The students can normally complete this module within 4 lab meetings instead of the allocated 5 meetings.

Casting:

Since there is only one practice pattern and one base pattern to cast, the students can normally complete this lab within 4 meetings, allowing additional time to begin fabricating the engine components on the mills and lathes.

Table 2
Table of Present Laboratory Schedule

Labs sessions	Group 1	Group 2	Group 3	Group 4
1	**Safety**	**Safety**	**Safety**	**Safety**
2 - 6	*Milling & Lathe*	*Hand Tools & Sheet Metal*	*Welding & Joining*	*CNC Machining*
7 - 11	*CNC Machining*	*Milling & Lathe*	*Hand Tools & Sheet Metal*	*Foundry*
12 - 16	*Foundry*	*CNC Machining*	*Milling & Lathe*	*Welding & Joining*
17 - 21	*Welding & Joining*	*Foundry*	*CNC Machining*	*Hand Tools & Sheet Metal*
22 - 26	*Hand Tools & Sheet Metal*	*Welding & Joining*	*Foundry*	*Milling & Lathe*
27-30	*Wrap up*	*Wrap up*	*Wrap up*	*Wrap up*

In addition to the manufacturing of the small engine, each group is required to produce a 1250 word project report. The report, as a minimum, is to include:

- A minimum 2-paragraph statement on "reverse engineering"
- A detailed description on the actual engine design how and why the engine functions, include key features, limitations, etc (use the internet and library resources)
- A section on the processes used (mill, lathe, CNC) pertaining to difficulties and problems encountered. You should include a description of changes that you had to make to the original drawings (engineering changes) while machining.
- Conclusion: Your insight on the project
- All component drawings
- Assembly drawing
- BOM
- Routing plans
- Inspection sheet (excel)
    - Include an explanation of any dimension not met and why
- Sample calculations (feeds, speeds, etc)
- Bibliography
- Photos

The pilot program was a success for both the students and the program. The participants became much stronger engineering students with a better understanding of applying tolerances, proper dimensioning, and attention to details while being able to produce a working model. The program (MET) benefited by introducing needed information to the students that they would not otherwise receive in a hands-on or classroom environment.
The Student Rating of Teaching Effectiveness (SRTE) for the past spring semester of 2003 was 6.67/7.0 (95%) for the course and 6.17/7.0 for the instructor (88%). This is a dramatic increase from the previous years.

Figure 1.
Picture of completed engine model

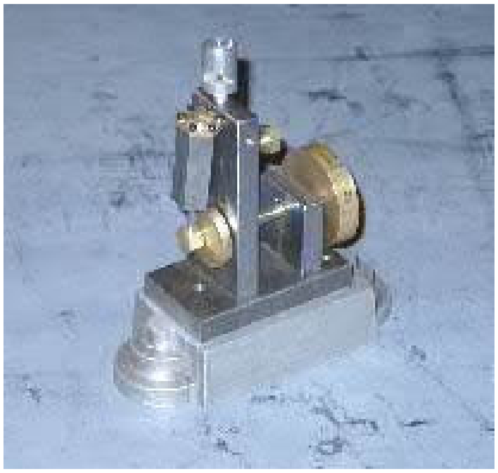
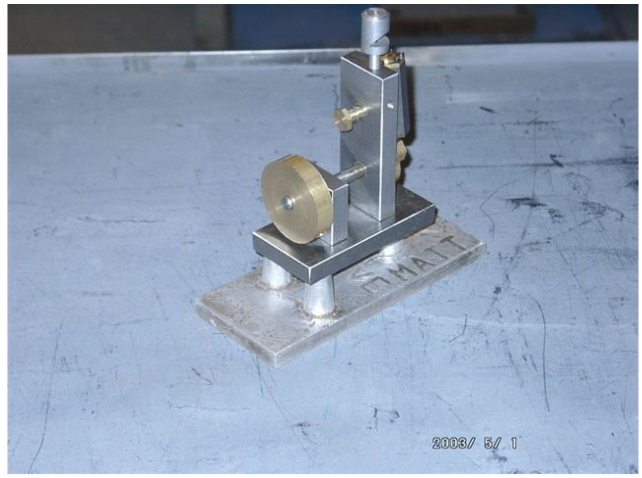
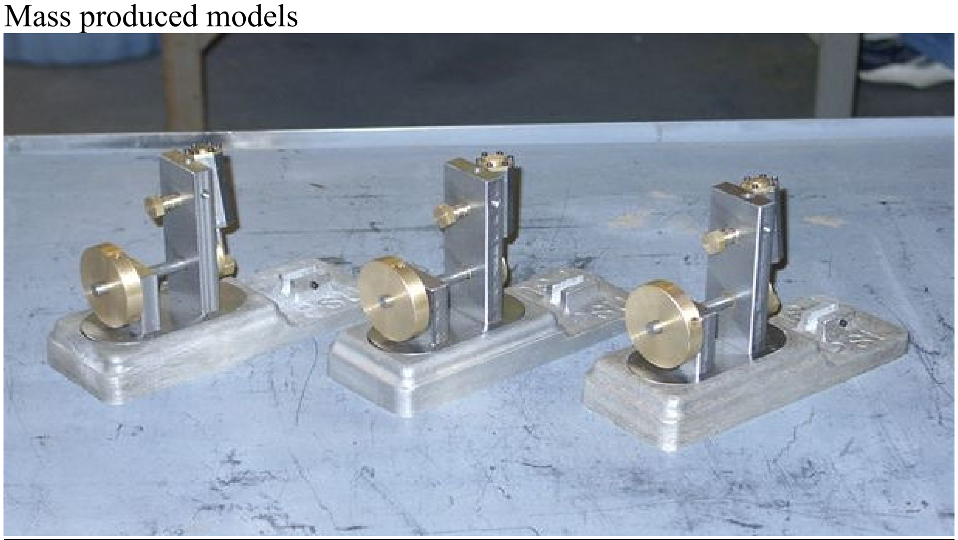


Figure 2.
Picture of completed engine model



Note of Interest: One group of students was so motivated by the pilot program that they mass produced their model so that each of the 3 students in the group could have a model to keep. In addition, this group's models performed dramatically better than any other groups.

Figure 3.
Mass produced models



<u>Future Plan:</u>

At the end of the semesters, the students were asked what improvements could be made to additionally enhance the project. Of the many suggestions from the students, two topics were repeatedly mentioned.

The first suggestion was that when the groups have completed the drawings and planning for the engine, they should exchange the manufacturing responsibility with another group to make. Any changes to the design would require a consultation with the design team and the drawings altered to reflect a revision change. This is the method that the manufacturing industry actually follows; machinists do not normally alter the dimensions, tolerance, or design without the engineering designer's approval. This suggestion will be incorporated in the current Spring 2004 semester to determine the benefit to the class.

The second suggestion was that additional models be available to choose from of a similar complexity. From the same source (Nimco, Inc)[4] several different model plans are available such as the Two-Poster Engine and the Elbow Steam Engine. Models of these designs have begun and should be available for the Spring 2005 semester.

Conclusion:

One of the main goals of the course is for the students to become familiar with the typical manufacturing processes and how the engineering community must be aware of specific limitations in the equipment. The pilot program was a success for both the students and the program. The participants became much stronger engineering students with a better understanding of applying tolerances, proper dimensioning, and attention to details while being able to produce a working model. In addition, the class became a more enjoyable and team orientated experience. The program (MET) benefited by introducing needed information to the students that they would not otherwise receive in any of the other available hands-on environments at Penn State Erie - The Behrend College. This experience helped to bridge the gap between theoretical and applied applications in manufacturing engineering.

Bibliography

1. Ssemakula, M (June 2002) "Introducing Hands-on Manufacturing Experience to Students." *2002 American Society for Engineering Education 2002 National Conference proceedings*. Session No. 3649

2. Degarmo, Paul E., Black, J.T., Kohser, Ronald A., (1999) *Materials and Processes in Manufacturing*. John Wiley & Sons, Inc. ISBN 0-471-36679-X

3. Kibbe, Richard R., Neely, John E., Meyer, Roland O., White, Warren T. (1999) *Machine Tool Practices*. Prentice-Hall, Inc. ISBN 0-13-270232-0

4. Engine Plans: Nimco, Inc. www.nimcoinc.com

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