Using a Two-Cycle Engine to Integrate Manufacturing Engineering Technology Curriculum

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Abstract – In an effort to increase the richness and scope of our students' learning experience, the Manufacturing Engineering Technology program at the University of Memphis is developing a curriculum context based on a .40 in^3, two-cycle engine. The purpose this project is to provide a real-world, product-based framework with which to integrate and expand the learning experiences from different courses and lab exercises. As students are exposed to the design, manufacturing, and quality challenges presented by the project, they are better able to see the limitations and constraints that would otherwise be simply theoretical and easy to ignore. This paper gives an overview of the project, and outlines some of the successes as well as some of the shortcomings experienced by integrating the curriculum in this way.

Keywords: Curriculum Integration, Engineering Technology, Manufacturing, Product Realization, Rapid Prototyping.

INTRODUCTION

The use of capstone projects to integrate and apply student knowledge is common practice, and not without reason. The benefit obtained when students experience their knowledge in action is hard to understate. It is this kind of experience that has driven the development the integrating curriculum context that is discussed in this paper. The goal of this project is to distribute some of the capstone design experience throughout the Manufacturing Engineering Technology curriculum at the University of Memphis. The integrating context is, in this case, a product -- specifically, a two-cycle model airplane engine. Through a sequence of several existing courses, students design, document, and build, and test a number of complete engines. The project is being implemented by replacing existing lab exercises with the context-based assignments. This paper will discuss the development and progress of the project, how it is used to integrate various coursework, as well as some of the disadvantages of using this kind of integrating context.

BACKGROUND

The Engineering Technology Department at the University of Memphis consists of ten full-time faculty members. Four of these (one of whom is the department chair) comprise the Manufacturing Engineering Technology program. Some courses are taught by adjunct faculty, generally from local industry. Our student population comes from a diverse background, and many are non-traditional students who have returned to college from the workforce. The diversity of the group in terms of work experience can be a hindrance or an advantage depending on the approach used in the classroom. The integrated context makes the most of this situation because it lends itself to a team approach, leveraging the knowledge possesses by the more experienced members, while providing a real-world platform for developing the skills of the less experienced.

Another benefit of the integrating project has been the incorporation of previously under-utilized equipment into the coursework. For example, the project relies on rapid prototyping, sand casting, and CNC machining. Rapid prototyping and lean product development have been the subject of much research recently, and have been incorporated into many schools' curriculum [Renuka and Thota, 1]. The Engineering Technology Department, along

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with Mechanical Engineering at the University of Memphis recently acquired a Stratysis Dimension SST fused deposition modeler. Prior to the development of the engine project, this equipment was used to produce isolated, open-ended projects. The engine project places the role of the models produced squarely in the production environment. The models are not the end product, but become casting patterns that must function, and produce cast metal parts that must function as well.

As they progress through their coursework, students experience the engine project from various perspectives. They prepare working drawings that will be used to create CNC machining programs, and they assign tolerances that will later drive quality characteristics. Although the work may occur in different semesters, each class is treated as if it is occurring simultaneously with the other activities, resulting in a tangible experience of concurrent engineering.

The project, in its current form, grew out of a series of senior projects that incorporated the rapid prototyping, sand casting, and CNC equipment into design projects. As student work on these project progressed, it became feasible to incorporate some of these activities into the curriculum of other courses.

METHOD

The design was reverse engineered from a commercially available two-cycle engine. The engine consists of twelve components that are currently being made by students. In addition to these, a needle valve, fasteners, and a few other components (considered purchase items) are incorporated from the OEM engine or purchased separately.

The student's exposure to the project is determined by the course sequence. This means that normally, their first involvement is through the second level manufacturing processes course. In this course (METH 3421 – Manufacturing Processes II), the project has replaced a laboratory exercise in sand casting. The old lab consisted of casting a single 4" flywheel from a single-sided wooden pattern. The integrated lab which replaced this lab uses a split pattern of the engine block (Figure 1) made on the fused deposition modeler. The pattern was scaled up by 4.5% to allow for shrinkage, and includes an interlocking sprue, riser and runner system. The development of the casting patterns and technique was the result of a senior problem that was focused on improving the casting process. Examples from some of the earlier, less successful castings have been retained and provide examples of shrinkage, distortion and porosity. Blocks that were made from earlier casting (before the total shrinkage value was determined) demonstrate the effect shrinkage has on further operations. The goal of this type of integration is to go beyond understanding the technology to adaptation to leveraging of emerging technology.

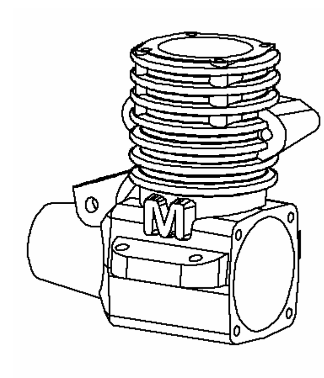

Figure 1 – Engine Block Design

During the same semester, students typically take a materials course (METH 3408 – Industrial Materials) in which they perform mechanical testing of various materials. Previously, the labs had been done in isolation of unrelated materials, now the course draws on the integrating product to develop material specifications, and perform tests related to the specifications for the engine materials.

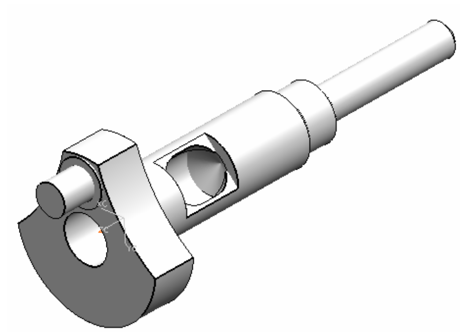

Figure 2 – Unparameterized Model

The following semester, students use Unigraphics to reverse engineer the engine. In the senior level CAD course (METH 4472 – Computer-Aided Design) the students are provided unparameterized models (Figure 2) of all of the engine parts. The students create working drawings from dimensions they measure on these models, and use their working drawings to create parametric models of the components. For some of the components, only functional parameters are given, and students are required to develop designs that function and can be manufactured by the equipment available. The context provides it own limitations, and gives students a more realistic idea of concepts such as design for manufacture. Additionally, students determine acceptable tolerances for certain components that are manufactured in the Computer-Aided Manufacturing (CAM) class and evaluated by the Statistical Quality Control class.

In what is usually their final semester, students take three courses that incorporate the engine. These are METH 4476 Computer-Aided Manufacturing, METH 4462 – Statistical Quality Control (SQC), and METH 4571 – Tool Design. Most of the production takes place in the Computer-Aided Manufacturing course. This course requires students to take the parametric models created by the CAD class and create code to machine the various components (Figure 3). Some of the labs require writing G-Code manually, such as the lathe operations on the crankshaft, while others incorporate the Manufacturing Application of Unigraphics NX3, while some use Mastercam Version X. In the Statistical Quality Control course, the process of machining the piston is examined. Using the tolerances defined by students in the CAD course, students study the process capability and try to reduce variability. In the Tool Design course, application is made as is necessary for the production and improvement of the components. Several of the machining fixtures were designed as part of this course, and the plan is to use this course to develop punch-press tooling to create gaskets and brackets that are currently treated as purchase parts.

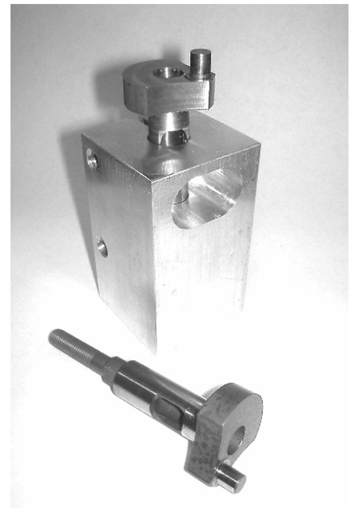

Figure 3 – Machined Components

RESULTS

Student response to the project has been extremely positive. Although no formal analysis has yet been conducted, it appears an overwhelming majority of students enjoy working on the project. By its nature, the project lends itself to a more involved discussion of the concepts as they are presented. The concepts no longer exist as isolated cases, but rather are parts of a whole. Students can see that a change in the working drawing has an effect that permeates throughout the entire production environment. On the other hand, the challenges presented by the project are real challenges that require real solutions, or else the entire project fails.

Successes

The advantages of integrating the curriculum in this way include an increased emphasis on team-based, experiential learning; increased opportunities to improve problem solving skills (there are more problems now); and judging by the number of students requesting to work on the project as part of their senior problem, an increased level of student interest.

The nature of the project, with its self-defining limitations, makes it a good fit for team-based learning. Teams are generally given an objective, and are limited by the equipment and material available. As the project continues to mature, it will become more formalized, and economic aspects of the project will become more realistic. For example, in the CAM course, the current emphasis is on successfully manufacturing the parts. Each team is assigned a specific group of components and fixtures, and they are required to successfully machine each of them. In the future, the teams projects will be "billed" a certain labor rate, material costs, machine time, and overhead. The project is flexible enough that it can be integrated at varying levels in any of the courses where it is used.

Student interest in the project has been extremely encouraging. Several students have chosen to develop some element of the engine as part of their senior project. The results of almost all of these projects have been excellent. Since the students are involved in the design and production of the engine, they tend to take ownership of the ideas behind the work. Overwhelmingly, students live up to the challenges they are presented by the project, they tend to exhibit a good degree of pride in their workmanship.

Shortcomings/limitations

Of course, no project is without some limitations. Some of the disadvantages of the project include a limitation of student's scope, a less generalized treatment of the material, a degree of inflexibility, and the time requirements of faculty.

As Sirinterlikci and Mativo [4] have observed, this type of project tends to narrow the students' focus. Instead of seeing the concepts as they relate to manufacturing in general, some students see the application to small engine manufacturing specifically. I have tried to be conscious of this problem, and have tried to limit the overall percentage of integrated material to a realistic, manageable proportion. In most of the courses where it is used, the engine context usually makes up less than half of the lab material, and a much smaller portion (less than five percent) of the lecture material. Additionally, the project is only integrated in the six courses outlined above, with no plans of further integration.

The inflexibility of the project can be an issue, but as it matures, this will become less of a problem. There is a significant lag effect between changes that occur in one course as they propagate throughout the integrated curriculum. This effect is mitigated by "freezing" the documentation of the project within each course. The students treat the electronic models as if they are the masters, but the real documentation that is incorporated is under faculty control. The changes made within a single course are carefully incorporated in the background by faculty. For example, if a student team fails to create acceptable cutting tool paths in the CAM course, the original programs developed in previous semesters can be used as a backup. The team may generate an engineering change request or change order that is implemented in a single course, but not actually implemented in the other courses. This gives the illusion of concurrent engineering without the unrealistic burden of faculty management of real-time changes.

The issue of faculty effort and involvement is an issue that will hopefully also diminish as the project matures. The hope is that the labs will become finalized, and changes will tend to slow down. This will allow labs to be carried out within the context of the engine, but without the extra effort of coordinating what happens in one course with what happens in another. Since it is in its early stages, however, the project has demanded an inordinate amount of faculty effort.

CONCLUSION

Although the project is not without its problems, the overall benefit to student understanding has been extremely gratifying. In its current form, the integrating project has been incorporated into coursework for one year, and the results justify further work to complete the project and further integrate it into the course and lab work. Student interest in the project is high, and the quality of student work related to the project has been more than satisfactory. Although it requires more effort, the ability of this kind of project to bring together so many of the techniques used in the field of manufacturing make it an ideal solution to many of the problems facing faculty in our program.

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Robert Hewitt is an assistant professor and the program coordinator for the Manufacturing Engineering Technology program at the University of Memphis. He has significant experience in the automotive and power generation industries, and has been teaching at the University of Memphis for over eight years. He is a member of the Society of Manufacturing Engineers, the American Society for Engineering Education, and the Honor Society of Phi Kappa Phi. His research interests are in the areas of engineering education and information technology for manufacturing.