AC 2008-1870: MECHANICAL ENGINEERING TECHNOLOGY SENIOR YEAR COURSE INTEGRATION MODEL

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Mechanical Engineering Technology Senior Year Course Integration Model

Abstract

As part of a recently completed Mechanical Engineering Technology (MET) curriculum review and enhancement exercise, many course level improvement opportunities were identified and plans were developed for implementation of those improvements. These plans included both course content enhancement, as well as teaching pedagogy modification. Most importantly, the improvements were designed to support defined core competencies of the MET program and to build and develop these core competencies in our students through curriculum integration. Inherently, MET is an applications oriented curriculum, and thus aligns itself well with project-based teaching and learning models in these core courses. In support of defined course improvements, and to support core competency development, the MET program is developing a project-based model for integrating the senior year MET core courses with the senior year capstone design and build courses. This paper will detail the methodology utilized to integrate two courses, MET460 – Advanced Instrumentation, and MET 449 – Design for Manufacturing and Tooling with projects assigned through the senior capstone course sequence (MET 456 and MET 457). Specifically, the course integration model will be outlined, the methodology utilized to develop this model, as well as benefits of implementation will be presented, and model effectiveness will be assessed and reported. Finally, a plan for implementing this model into other courses in the core MET curriculum, as well as for consideration for use by other programs in the college, will be presented.

Introduction

The Mechanical Engineering Technology (MET) program at Montana State University (MSU) is committed to preparing graduates to immediately contribute to an increasingly diverse employer base upon graduation, as well as prepare graduates for continued success in their chosen careers. The changing needs of this constituency base must also be supported in order to develop an educational system that effectively supports the development of the valuable skills and attributes necessary for our graduates to be successful in their chosen careers. Based upon this commitment, the MET program must quickly adapt to technological changes, as well as continually evolve and improve to implement changes that will support all involved. All of this must be done without diluting the learning process. Guidance is provided by Glatthorn and Jailall[1] through the following recommendations related to effective curriculum design:

- Curriculum should be designed to provide greater depth and less superficial coverage
- Curriculum should be designed to focus on problem solving that requires learning strategies
- Curriculum should be designed to emphasize both skills and knowledge of the subjects
- Curriculum should be designed to provide for students' individual differences
- Curriculum should be designed to offer a common core to all students
- Curriculum should be designed to coordinate related subjects, various levels of the same subject, and interrelationships of topics throughout

- Curriculum should be designed to integrate selectively verses excessively
- Curriculum should be designed to give students the tools they need to make the society an even better one

Curriculum development activity, within the quality improvement model, is ongoing in an effort to meet these recommendations through continuous, appropriate, research driven change. Change should not be limited to course content, however. Change also encompasses how we as faculty "teach" our students. The methods and teaching pedagogies that best support development of the necessary skills must also be addressed and improved. Research has shown that all students learn differently[2]. While it may not be possible to understand each individual students learning style, faculty should strive to provide effective learning opportunities for each student. Learning is influenced by several factors as Cannon and Newble[3] identify as:

1. Student characteristics - These include individual differences of the students, previous learning experiences of students, and current understanding of the subject.
2. Context characteristics - These include the ethos (philosophy) of the department organizing the course and the characteristics of the curriculum.
3. Teacher's approach - This can vary considerably and each teacher must be aware of the approach they take and what impact that approach has on student learning.

The MET program is committed to undergraduate education, as well as meeting all outcomes defined to support ABET accreditation requirements[4]. Implementing thoughtful and effective curriculum improvements, as well as improving teaching methods is an essential part of meeting the goals and outcomes of an effective program. This paper will detail the methodology utilized to integrate two courses; MET 449 (Design for Manufacturing and Tooling) and MET 460 (Advanced Instrumentation and Test), with projects assigned through the senior capstone course sequence (MET 456 and MET 457).

Background

The mission of the Mechanical Engineering Technology program at MSU is to "prepare students for successful Mechanical Engineering Technology careers, responsible citizenship, and continued professional growth"[5]. The MET mission statement still provides an effective direction, or philosophy, and supports the college and department missions.

The MET objectives defined for MET graduates states that "Mechanical Engineering Technology Graduates employed in the field will undertake professional careers in engineering technology, employ effective communication, work in multidisciplinary professional teams, engage in life-long learning, contribute to industry and society, in Montana or elsewhere, engage in professional problem-solving activities using applied methods, assume leadership roles that contribute to the success of their organization or community, and advance in the profession[5].

The MET outcomes defined for MET graduate's states that "The MET program seeks to produce graduates with a good foundation in engineering fundamentals as well as one strong in applications, design, problem recognition and resolution, project management, communication, and professional and ethical responsibility[5].

Although our mission, objectives, and outcomes are well defined, changes in the U.S. economy have led to a greater diversification of employers seeking our graduates. To effectively support this diversification of employment opportunities, continuously improve the MET program, and enable the program to produce graduates capable of succeeding in the future, all aspects of the current MET program were re-evaluated. With the mission, objectives, and outcomes providing direction, the MET curriculum committee at MSU, with the support of all constituents of the program, completed a review of the entire curriculum[6, 7]. The review process utilized is summarized in Figure 1.

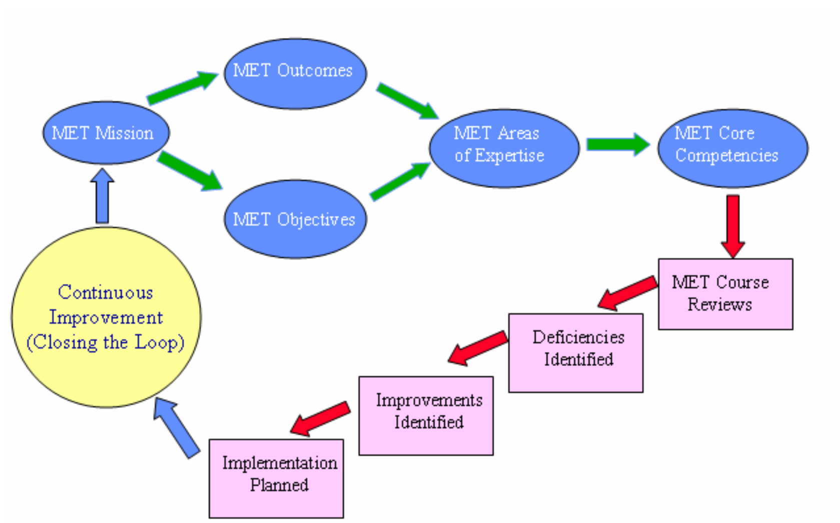


Figure 1: MET Curriculum Review Process

MET "Areas of Expertise" and "Core Competencies" related to those expertise areas were identified and documented. Although we would like to support all aspects of mechanical engineering, we are limited by resources. Therefore, the program focus is limited to defined "Areas of Expertise". These are:

- Engineering Fundamentals
- Manufacturing Applications
- Thermal / Energy Sciences
- Mechanical Design
- Professional Skills

Within each area of expertise, core-competencies were defined[6] and then utilized to develop outcomes within each course to support core competency development. Finally, core courses were reviewed (see table 1 for review process) and improvement opportunities identified.

Table 1 – MET course review process

Provide overview of current course
- Review expected outcomes of course
- Review topics currently covered
- Discuss effectiveness of course as designed (Assessment)
- Assess current teaching pedagogy of course

Review assessment data and ABET criteria interactions:
Evaluate related core competencies of course
Assess effectiveness of course
- Outcomes being met?
- Core Competencies effectively supported?

Propose and implement changes as necessary
- Develop implementation schedule
- Assign action
- Follow up and continuously improve the course

The integrated senior year model supports the improvement plan implementation.

Current State of the Senior Year Course Structure

Currently, the senior year MET core course structure at MSU includes several courses that build on learning outcomes from previous courses[5]. However, these courses do not effectively integrate with the senior capstone course. The course structure is shown in figure 2.

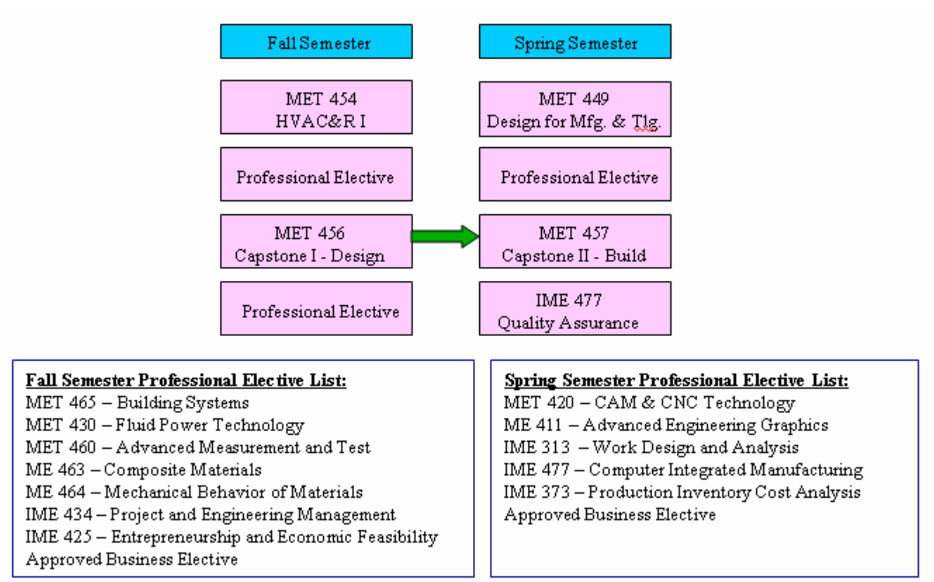


Figure 2: MET Senior Year Core Courses (Current Structure)

Students are free to select any professional elective they desire. Along with a lack of integration, little consideration is given to aligning these professional elective selections with professional interests of each student. In addition, each senior core MET course also culminates with a required, problem-based[3] “final project”. While this approach provides an effective way of meeting individual course outcomes, through integration, they could better support meeting program outcomes as well. An additional consequence of this organizational style was the creation or redundancy of course expectation and an overlap of activities. Students were finding it difficult to juggle all of these individual course projects and still fulfill all the requirements of their senior capstone course. The consensus feeling was that this arrangement contributed to a dilution of the learning experience, rather than being a benefit. In essence, students were spending too much time managing their time (which was in short supply).

Initial Integration Model

Initial implementation involved selecting senior core courses and making a commitment to integrate these with the senior capstone courses. The selected courses were MET 460 (Advanced Instrumentation and Test) and ME 448 (Design of Tooling). MET 460 is offered in the fall semester, and ME 448 is offered in the spring semester. Figure 3 represents the desired model.

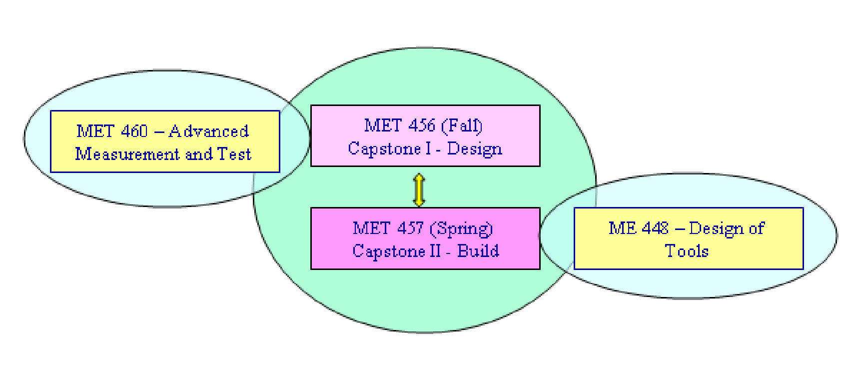


Figure 3: Initial Integration Model

ME 448 – Design of Tools – Spring 2007

This was a required course for mechanical engineering technology students and a professional elective course for mechanical engineering and industrial engineering students. It is offered only in the spring semester of the senior year. This course is designed to provide an overview of production systems and lean manufacturing fundamentals and principles. In addition, design for assembly and design for manufacturing principles are introduced and applied. Finally, fundament tool design principles, including tooling materials, work holding principles, jig and fixture design, assembly tool design, design of tools for inspection and gaging, and tool fabrication techniques are introduced. Students entering this course are expected to have completed a materials science course, manufacturing processes course and basic training in machining and welding processes. Expected course outcomes are to:

- Develop an understanding of production systems within manufacturing industries
- Understand and apply general design principles for manufacturability
- Understand and apply general design principles for assembly in the context of product development
- Understand and apply the fundamental concepts of tool design
- Analyze a product design and develop a plan for manufacture
- Implement a plan for manufacture for a product

This course is a three credit, lecture based course that culminates in a project-based tool design assignment intending to provide an opportunity to apply the competencies gained in the course and contribute to meeting the specified course outcomes. Students can choose projects from a list provided by the instructor, or they can be designed to contribute to the success of each student group's current capstone project. The emphasis of this course is design; therefore, no project build was required. The requirements for projects, including the capstone-based projects are shown in figure 4.

ME 448 - DESIGN OF TOOLS
Team Design Project - SPRING SEMESTER 2007

Assigned: **03/09/07**
Due Dates: **04/27/07**

Each team (3 to 4 members) will be responsible for the following:

1. Design project selection / proposal.
2. Project Plan.
3. Design concept development and selection.
4. Complete set of tool drawings describing the design.
5. Tool Usage Instruction Sheet describing the method of tool use.
6. Description of the suggested method of tool fabrication.
7. Final Project Report organizing all the above into an acceptable format.

Each group will select a project from the following options:

1. Drill Jig for Roller Fitting
2. Drill Jig for Switch Support
3. Mill Fixture for Switch Support
4. Boring Fixture for Door Stop Fitting
5. Student selected (and instructor approved) project

Student Selected Project Criteria:

Each design team will be responsible for identifying a component processing and production plan in support of their assigned capstone project. This plan will be based on the assumption that your particular product will be placed into production, at a production rate much greater than one. Your plans must include:

1. Operations sequencing for each component of your design.
2. Operations sequencing for the assembly of your component.
3. Identification of machines that would be utilized for manufacture of your product.
4. Identification of the tooling required to manufacture the product.
5. Concept design of one of the tools involved in manufacture of the product.
6. Final Project Report organizing all the above into an acceptable format.

Figure 4: Term Design Project Requirements

Four student design groups selected projects that supported their capstone projects. Table 2 summarizes these.

Table 2 - Student Selected Projects

Project Name	Related Capstone Project
Lathe Fish-mouthing Fixture	SAE Car – Capstone project
Venturi Restrictor Mold	SAE Car – Capstone project
Rocket Airframe Fin Fixture	Rocket Frame group – Capstone project
SOFC Manifold Jig / Fixture	Fuel Cell – Capstone project

Rather than discuss these projects in detail, the benefits and challenges will be shared. Benefits of this new model include:

- Outcomes of the course were met
- Groups were able to build the prototype designs (because they were combined)
- Groups were consistent with Capstone groups. Therefore, another meeting coordination activity was not required.
- Students better understood the design of the product that the tooling was designed to support
- Students thought that they obtained a better understanding of the benefits of planning for manufacturing
- This integrated activity more effectively contributes to overall program outcomes

Some of the challenges that will have to be overcome are:

- Not all students in the tooling course were involved in capstone at the time.
- Additional build time was required in the machine shop – with added cost and limited funding to support.
- Lecture time was difficult to organize to best support the needs of this type of course.
- More dedicated lab time is required to better support project development

Student surveys, along with instructor assessment, determined that a practical lab experiences would enhance the course material and provide students with better opportunities to apply many of these fundamentals. Therefore, beginning in spring 2008, the course will become a two credit lecture, one credit lab format. The majority of the lab time will support the design and build of capstone project tooling requirements.

MET 460 – Advanced Instrumentation and Test

The initial offering of this course proceeded with limited enrollment of eight students so that a single group project could be utilized. The project selected was the design and fabrication of on-board instrumentation system for the SAE Formula car. The course activities included steps of defining system architecture, specification of design/performance requirements, component selection, data acquisition system programming, and integration of the resulting prototype into the existing vehicle. Benefits of this new model include:

- MET students were able to reduce academic topics to practice.

- Students were involved in all phases of the process of creating a working system, from conceptual design through test of the completed system.
- Students were challenged by the varied skills needed and range of topics covered, ensuring rigor in the course.
- The overall topic – gathering data from a race car – was a topic that held the interest of students in the class.

A total of 16 channels of data from eight types of sensors were integrated into this vehicle to monitor performance-related parameters. Figure 5 illustrates the SAE car with the body removed to display some of the instrumentation wiring installed, while Figure 6 shows a wheel position sensor and brake temperature sensor installed on the 2007 MSU FSAE competition race car. On-board computer data acquisition was accomplished using a DC-powered National Instruments CRIO computer system. Presently this system is being enhanced with GPS location and wireless LAN system to beam acquired data to a collection station in the pits, in real-time.

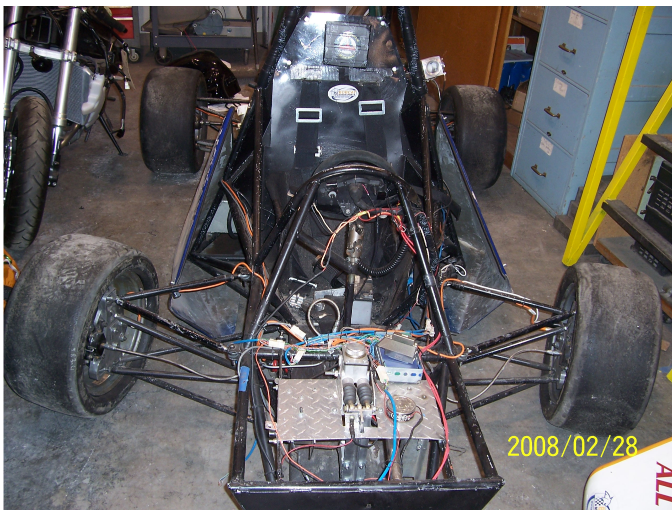


Figure 5: Instrumented 2007 MSU FSAE Car

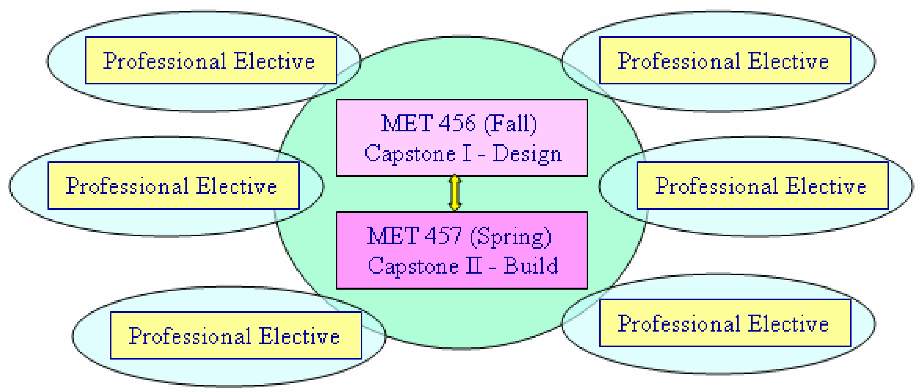
Figure 6: Wheel Position Sensor and Brake Temperature Sensor

Some of the challenges that will have to be overcome are:

- A new project or sub-project may have to be found each time the course is offered.
- Increased enrollment may require more than one project, diluting instructor's ability to lecture and guide the class on specific shared instrumentation elements.
- Student participants will graduate and move on before full system testing is completed. Thus the prototype product that may be difficult to troubleshoot and modify in the future.

Course Structure for Integrated Senior Year

A desired outcome of the curriculum review activity at MSU was to provide students more flexibility and guidance when planning their senior year course selections. We wanted them to be able to direct their education towards their professional interests within the program defined areas of expertise. Toward that goal, the MET program reorganized to provide more professional electives, as well as changed some required courses to professional elective courses. Figure 7 illustrates the future plan for senior year courses.



Fall Semester Professional Elective List:
MET 465 – Building Systems
MET 454 – HVAC&R I
MET 430 – Fluid Power Technology
MET 460 – Advanced Measurement and Test
MET 477 – Production Systems and Quality in Mfg.
ME 463 – Composite Materials
ME 464 – Mechanical Behavior of Materials
IME 434 – Project and Engineering Management
IME 425 – Entrepreneurship and Economic Feasibility
Approved Business Elective

Spring Semester Professional Elective List:
MET 420 – CAM & CNC Technology
MET 449 – Design for Manufacturing and Tooling
MET 458 – HVAC&R II
ME 411 – Advanced Engineering Graphics
IME 313 – Work Design and Analysis
IME 477 – Computer Integrated Manufacturing
IME 373 – Production Inventory Cost Analysis
Approved Business Elective

Figure 7: MET Senior Year Core Course Integration (Proposed Structure)

Ultimately, our goal is to provide an integrated, problem-based, senior year experience that will enable each student to meet the expected course outcomes while contributing to the program outcomes, as well as develop their own professional interests. Each selected course would integrate project requirements with the capstone course sequence, as well as with other courses selected. Reaching this goal requires both commitment and organization from all faculty members within the department. We are a long way from accomplishing a completely integrated senior year. We can, however, provide the impetus and develop a plan for the future through the courses that we do control. To alleviate the scheduling concerns of students without compromising course outcomes, a new approach was tested in two senior core classes, with the intent of expanding this approach to all senior core courses in the future.

MET 449 / ME 448 – Design for Manufacturing and Tooling – Spring 2008

To more effectively support the integrated senior year model, the design for tooling class was cross-listed as MET 449 and revised to a two credit lecture, one credit lab format. This change was made because this is a required MET course and is controlled by the MET curriculum committee. The title changed to better represent the course topics. Assessment data from spring 2007 also drove out the requirement for a lab component. This lab time will provide the scheduled, focused time required to effectively integrate the project build component into the course, as well as better support the capstone integration. Course outcomes for this course are the same as for the spring 2007 course, however, to the greatest extent possible, all projects will be designed to support enrolled students senior capstone projects. For those students not enrolled in capstone, the instructor will assign projects that will support other capstone group requirements, or other defined manufacturing and tooling needs within the college of engineering. The table below represents the type of projects that will be assigned.

Table 3 – Group Projects

Project	Capstone Support Project
SAE Car Weld Fixture	SAE Frame Group
SAE Car Test Fixture	SAE Frame Group
SAE Car Body Lay-up Mandrel	SAE Frame Group
Mill Fixtures	SAE Groups
HPV Test Stand	HPV Group
HPV Weld Fixture	HPV Group

For example, the group responsible for SAE Car Weld Fixture will design a fixture to hold the components of the car frame in place while welding. Figure 8 shows the current method being utilized. To improve quality, productivity, and safety, a modular type weld fixture will be designed and built to support SAE frame build in the future.

Figure 8: SAE Car Frame Weld Fitting

Team members will follow the engineering problem solving method while completing their projects. They will also incorporate project management skills through bi-weekly status reports to the course instructor and project customers. Ultimately, a prototype of their designs will be required to complete the project.

Conclusion

Curriculum improvement and development, within the continuous improvement model, has led to the development of an integrated senior year curriculum model. Mechanical Engineering Technology program mission, objectives, and outcomes[6], developed with ABET criteria and constituent input (students, industry, faculty, etc,) as a guide, provides the impetus for this development. Ultimately, we strive to design courses and activities within the curriculum that provide students with the most effective and technologically up to date skills required for them to be effective in their chosen career fields. We believe that this activity provided a strong first step. In the future, we will continue to work with the entire faculty of the college to enhance this model.

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