ASEE's 123rd Annual • Conference & Exposition • New Orleans, LA • June 26-29, 2016

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Paper ID #16422

Educational Innovations in an Introductory Materials Course

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Abstract

As students' pre-college experiences and approaches to learning change, finding effective new ways to deliver their instruction plays an increasingly important role in engineering technology education. The core question of how to best connect innovation in teaching with the creation of value in learning is a challenging one to all educators. The introductory materials course for the manufacturing and mechanical engineering technology degree programs at the campuses of Purdue University gives an overview of properties, processing, and applications of polymers, composites, and non-traditional materials commonly used in industry. Students develop problem solving skills through practice in the areas of materials selection, evaluation, measurement, testing and processing. Beginning in 2014, multiple innovations have been applied to this materials course at different campuses to address the needs of learners ranging from traditional full-time residential students coming directly from high school to mature, part-time commuter learners with careers. This paper presents the approaches taken to develop this course from existing learning objectives for delivery in two very different settings, to diverse learners in mechanical engineering technology. Learning outcomes resulting from lecture and laboratory innovations are considered.

Introduction

From the inception of baccalaureate engineering technology programs, faculty have struggled to find the right balance between technical, professional, and general education in their four-year curricula.[1] Implementation of legislated limits on credit hour requirements beginning in the 1990s adds a further curricular constraint.[2,3]. Effective in 2013 in Indiana, baccalaureate degree credit limits resulted in the removal of five credits from the manufacturing plan of study and seven credits from the mechanical plan. Ensuring that graduates continue to be well prepared for engineering technology careers within the constraints of reduced curricula requires better learning and more effective corresponding instruction. Lower than desired manufacturing and mechanical engineering technology retention rates juxtaposed against national calls for increasing the number of engineers and other STEM professionals also point to a need for instructional change.[4]. For these reasons, effective educational innovation must happen in engineering technology education. The strategic question of how to connect innovation in teaching with the creation of learning value is a challenging one for all technology educators and key to judging the usefulness of any instructional change.[5]. Simultaneously, instructors must strengthen their teaching outcomes and improve the learning process.[6]. While low-level innovation for the purpose of improving learning in the current course has been ongoing, more significant innovation is warranted.

Background Overview

Curriculum development in technology education originates with the implementation of established educational goals. These goals may be based on political, economic, and other related considerations beyond technical expertise, and guide engineering technology faculty as they help learners prepare for the global economy.[7] Moreover, the true overarching mission for the faculty is to increase the quantity, quality, and diversity of engineering technology graduates to meet current and future workforce needs. Achieving this mission necessitates fully innovated, problem-solving based curricula, collaborative teaching strategies, and extensive active-learning. Key quality elements for engineering technology graduates include understanding of design/development thinking and mastery of multiple problem solving methods. Similarly, the ability to innovate, to apply creativity to products and processes, and to effectively collaborate is imperative for excellent engineering/technology education. This mission, quality elements, and desired abilities helped drive these gateway course developments.

Mechanical Engineering Technology (MET) and Manufacturing Engineering Technology (MFET) programs were among the first to be developed in response to the Grinter Report's recommendation to create two paths to engineering careers, where engineering technology programs focus on educating engineering practitioners.[8] Several factors have contributed to recent jumps in popularity and corresponding enrollment growing pains, e.g., pre-college curricula like Project Lead the Way and the re-shoring of a number of manufacturing operations to the United States.[9] While industry acceptance of the engineering technology baccalaureate degree still lags engineering, the outstanding placement rate of graduates from these MET and MFET programs indicates their widespread recognition.[10]

At Purdue University, the MET program, offered at multiple campuses, focuses on "the methods, materials, machinery and manpower necessary to effectively operate in a manufacturing environment. Students will learn how to manage people, machines, and production resources to ensure maximum efficiency and safety"[10]. To do so, graduates possess skills in problem-solving, leadership and teamwork. In a compact, 120 semester credit hour curriculum, development of these skills begins in the very first course, MET 14400 Materials and Processes II. This course is the designated program gateway course since it includes exposure to many experiences and disciplinary elements that are core to the majors. The core technical content of the course is an overview of structures, properties, processing, and applications of polymers, composites, and emerging/alternate materials commonly used in industry. Problem solving skills are developed in the areas of selection, testing, and evaluation of materials and processes. Through ongoing interactions in the laboratory, a group project, and in-class activities, communication skills are enhanced to prepare for industrial and professional expectations. To inculcate understanding of the need for self-directed lifelong learning into these primarily fresh high school graduates, a small number of student-selected Professional Development Activities (PDAs) are embedded into the course. The purposes for implementing instructional innovations in this course are improving students learning outcomes, creating a good learning environment in this entry-level course, and preparing students for success in the baccalaureate degree program and beyond. The intended learning experience will produce students "who not only have deep knowledge, applied skills, and experiences in their chosen discipline, but also problem solving, critical thinking, communications, and leadership skills sought by industries and communities".[10] The Materials and Processes II course, an introductory class with no prerequisites that typically meets for two hours of lecture and two hours of laboratory content each week, contains fifteen core learning objectives that define its base learning expectations (shown in Table 1). Instructional delivery techniques are generally left to the discretion of each course instructor. This paper focuses on the approaches taken by two instructors as they work to increase achievement of learning objectives and raise retention rates through course improvements.

Table 1: Core Learning Objectives in MET 14400 Materials and Processes II

1.	Differentiate between the structure and characteristics of the major thermoplastic and thermoset polymers.
2.	Understand the terminology pertaining to industries involving polymers or alternative materials.
3.	Identify major traditional polymers and alternative materials used in the production of consumer products.
4.	Conduct material property tests using standard methods and instrumentation.
5.	Research polymeric materials and processes using various resources.
6.	Describe key design considerations for gating systems, molds and other process equipment components.
7.	Identify and describe the major molding, forming, shaping and joining processes used in the manufacture of polymeric products.
8.	Display safe and environmentally sound methods of working with polymeric materials and processes.
9.	Understand the concepts of lean manufacturing, sustainability, and product life cycle management with regards to polymers and alternative materials and processes.
10.	Describe how fibers and matrices are combined to form composites and explain why composites are used.
11.	Describe the fabrication techniques used to produce particulate, laminar, and fiber-reinforced composites.
12.	Describe biomaterials and biomedical device manufacturing concepts.
13.	Identify green materials and green manufacturing strategies.
14.	Describe the key difference between traditional manufacturing and industries such as pharmaceutical and biomedical device.
15.	Perform objective quality inspection, analyze basic material and manufacturing-related defects, and recommend appropriate modification that would be likely to reduce or eliminate the defects and/or provide for more efficient design and manufacturing.

Materials Course Innovations for a Large Class of Traditional College Students

Throughout 2015, multiple course modifications were implemented to better engage the primarily traditional freshmen students in MET 14400 Materials and Processes II and increase their attainment of course learning objectives. For spring 2015, the most significant innovation was the incorporation of a group design/build project. 28 student teams were tasked with identifying a product of interest, determining how to manufacture the polymer or composite product within project constraints on size and processes; developing supporting calculations, sketches, and other documentation; making or locating an appropriate mold; generating their product, and presenting their product to their lab colleagues. To facilitate completion of this project, the longstanding materials research presentation was eliminated and several modular laboratory activities were shifted to other lab sessions that had extra time available.

Students showed their ingenuity and produced a wide variety of items, some examples of which are shown in figure 1. Preferred processes were vacuum thermoforming and chemical foam molding. Based on spring 2015 end-of-course assessments for core learning objective 7 (CLO7), understanding of basic polymer processes improved significantly, with a few exceptions, as shown in figure 2. Previously, 50% to 60% of students demonstrated they should be able to identify and apply major polymer processes. Spring 2015 students' achievement pushed this to 82% learning success. Significant gains in learning were also evident for CLO6, gating, molds, and related design concerns, differentiating thermoplastics and thermosetting polymers (CLO1); and identifying which polymers are common in consumer products (CLO3).

Figures 1a Vacuum thermoformed multi-purpose tray; 1b, mustang emblem, 1c, hot dip casting phone case; 1d, rotational molded maracas

Unfortunately, success was not steady or enhanced for all core learning objectives through the adoption of the new product project. Of particular concern was the learning success drop for CLO10, basic types of composite materials, apparently due to the removal of the more extensive materials research project that had corresponded to CLO5. The product project generally went well, but its first iteration revealed that the product planning needs to be fairly structured to ensure students are developing basic engineering and project management skills. In addition, both the instructor and students were dissatisfied with the energy and engagement level of the spring 2015 class in the lecture setting. While keeping energized and connected to course content at 4:30 pm in a class of more than 100 students is often difficult, it is essential to improving student learning.[11, 12]

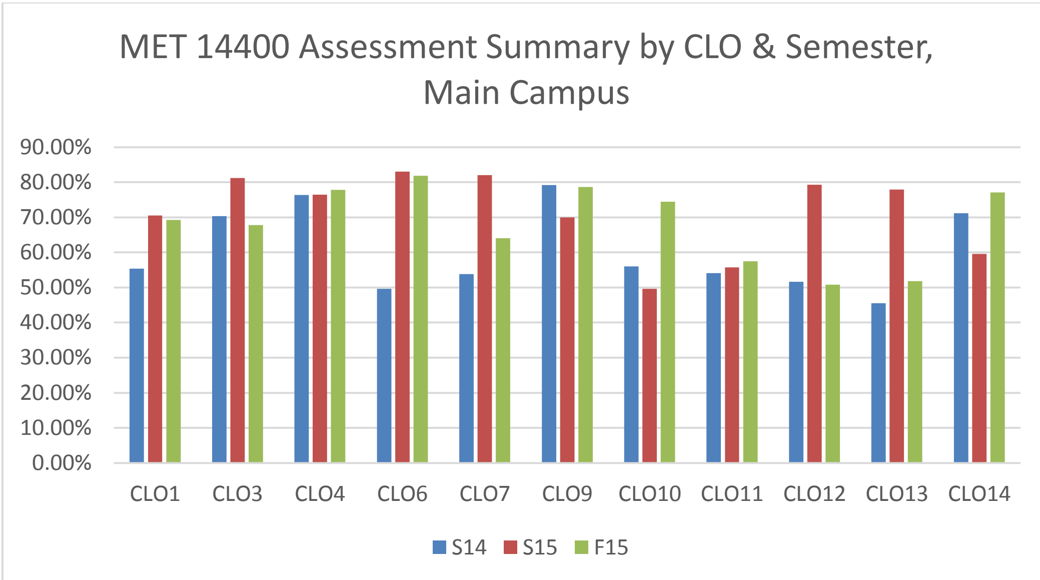

Figure 2: Core learning objective trends at the main campus, spring 2013 to fall 2015

Fall 2015 course innovations took three paths. For the lecture portion of the class, effort was made to increase informal active learning elements from nominally one activity per five lectures to about one activity per lecture to address lagging student interest and engagement. A materials research project was reintroduced in a slightly different form, moving from presentation on any new polymer or composite material to a written summary of a composite material that was listed in Granta™ CES EduPack Materials Selector software, Level 3. The product project was refined to strengthen requirements related to following a more engineering-oriented design process and completing process planning steps BEFORE attempting to make something and hoping it works out, a key differentiator between engineering design and tinkering.[13] As figure 2 indicates, achievement of some core learning objectives improved through course innovations while other areas saw a reduction in learning success due to the course innovations and modifications. Identification of polymer processes, CLO7, settled down somewhat in fall 2015 (still improved over pre-product project results). Understanding of composite materials and their constituent components jumped with the introduction of the composites research paper, while distinguishing between traditional and bio/pharma manufacturing constraints, CLO14, recovered to pre-spring 2015 , biomaterials and biomedical device manufacturing concerns, CLO12, and green materials and manufacturing methods, CLO13,all returned to slightly above pre-spring 2015 levels.

The student enrollment at the Kokomo campus has greatly increased since opening the baccalaureate degree program in spring 2015. In fall 2014, the MET 14400 Materials and Processes II course roster consisted of approximately five students, jumping to about 15 students in fall 2015. Processing laboratory activities were previously handled by compressing weeks of work into one intensive lab session at another campus. With the enrollment increase and corresponding course enhancements, more on-site laboratory activities were introduced. The new laboratory content and equipment purchases facilitate understanding of course learning outcomes through new experiences such as plastic molding and foaming processes. Students take a field trip to a local plastic injection molding facility during the semester. This visit enables students to learn and understand techniques of injection molding design and processing beyond the textbook through short-distance observations and detailed explanations from experienced industry engineers. There are two lab assessments, which consist of short reports that focus on analyzing the results and process of one of the polymer properties tests (tensile strength and hardness testing) and one of the plastics molding processes (injection, vacuum thermoforming, hot dipping, and chemical foam casting). Along with the lab assessments, a group project was developed to improve students' team work skills and their competence with results analyzation. Perhaps more significantly, the group project enables students to complete a process of self-learning. Each group picked a project topic relative to their study that had not been mentioned in lecture. Based on more than one month of research, they presented their project findings to the whole class. The presentation included audio/video materials to more clearly present their newfound knowledge. Unfortunately, it is hard to determine how much learning improvement may have resulted from these course innovations due to the change of program to MET and the very limited sample size in fall 2014. In comparison to the students at the main residential campus where more than 95^% of students taking this course are enrolled full time, about a third of the students at the Kokomo campus have a full-time job. While many of these jobs provide a degree of hands-on experience, all the MET 14400 course laboratory contents offered fresh and new experiences for the students. For the Kokomo campus students, attainment of CLO success varied somewhat randomly between full time and part time students. Figure 4 shows there is no significant difference between full time and part time students' attainment of CLO success. As at the main campus, CLO10 results are relatively low, and CLO4, CLO6, and CLO14 achievements are better than the others.

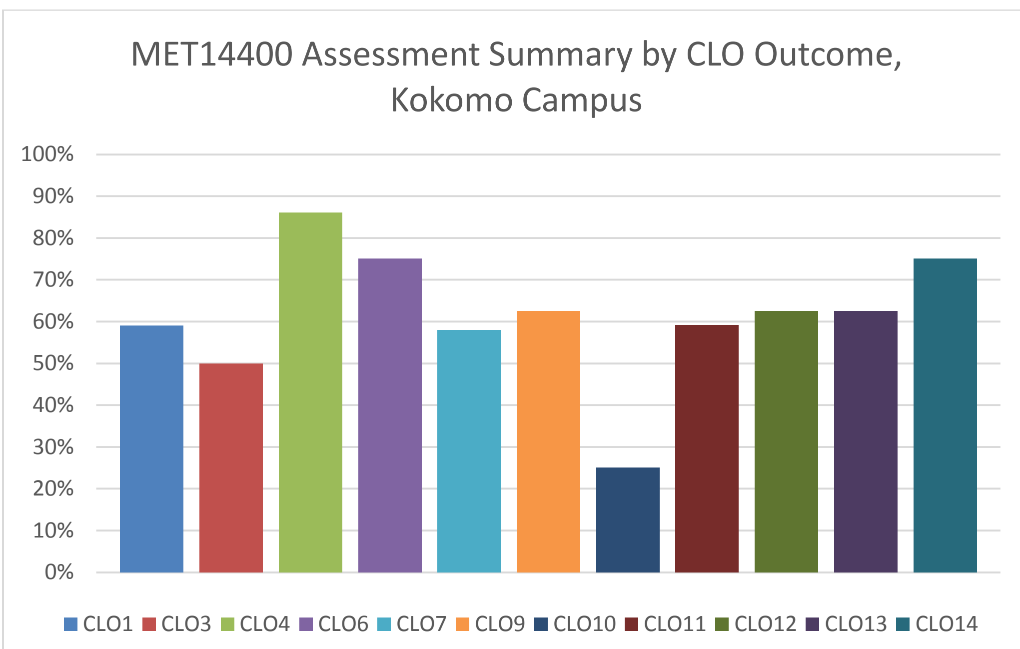

Figure 3. Core learning objective achievement at Kokomo campus, spring 2015

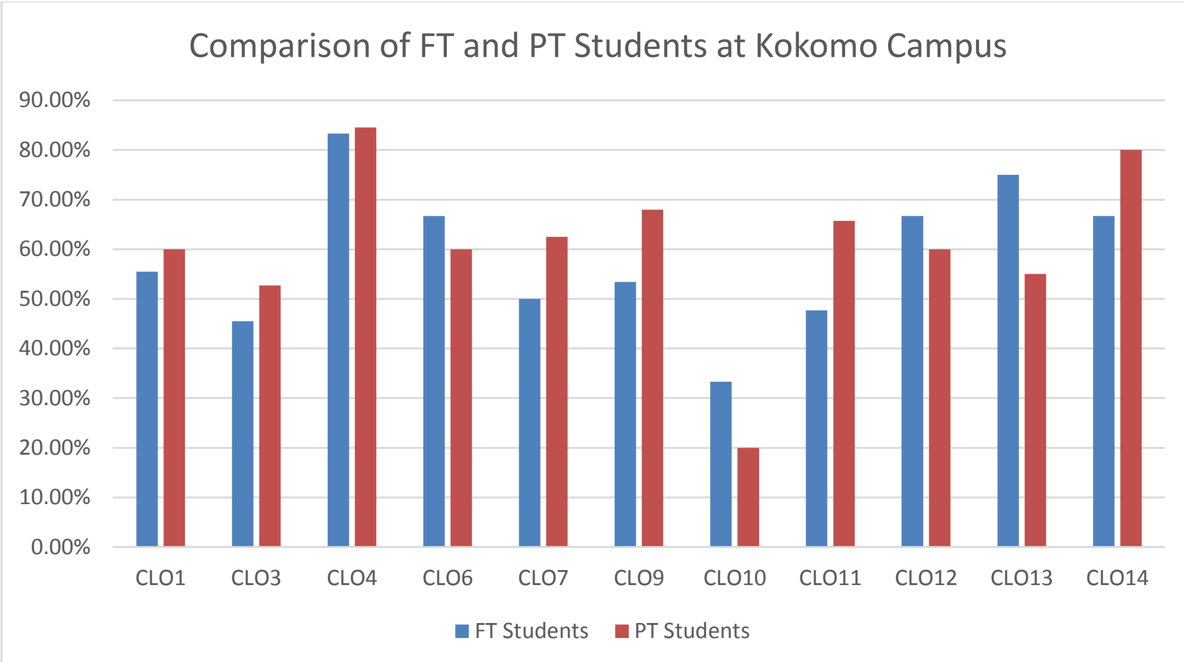

Figure 4. Core learning objective comparison between full time students and part time students at Kokomo campus, spring 2015

Lessons Learned and Next Steps

Student learning improved when they physically or mentally engaged with course content in a self-directed way. To a lesser extent, mentally engaging with course content through faculty-directed lecture learning activities improved the connection of course content to practice. Developing a product and researching a material of their choice enhanced understanding of core learning objectives. Awareness of related professional attributes tied to engineering design and project planning has happened, but students need much more exposure and direction to be appropriately prepared in this area. In response, product planning requirements have been strengthened for spring 2016 projects and beyond. Fundamental understanding of composite materials and manufacturing techniques has not been successfully addressed, as indicated by the low achievement of CLO10, especially. This low outcome means it is the prime target for innovation efforts to improve this portion of the course. In addition to continuing the composite materials research project which showed some promise, options include new lecture, homework and/or laboratory activities such as testing of composite material properties. A field trip to a composites production facility might have a strong impact on learning.

For the Kokomo campus, the other anticipated major innovation step is to adjust the existing group research project to adopt a group design project. The project will begin with the design purpose, brainstorming discussion, geometry development, materials selection, calculation of basic mechanical properties, process development, and cost estimating. A prototype could be 3D-printed to complete the work. As instructors of post-requisite course, the authors have found that students retain knowledge of the actions they have taken in the lab (e.g., conducting tensile and hardness tests), but do not remember much from their calculations. Increased practice with lab-based hand calculations and graph development may improve their knowledge retention.

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