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Assessment of the ABET Student Outcomes in a Service Learning based Subtractive Manufacturing Course

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Abstract

Hands-on learning is the core of Engineering Technology programs, and a high number of the courses is taught with the laboratory sections. This paper presents the service learning based enhancements made in one of the Engineering Technology courses. Course students learn manufacturing the complex machined workpieces using the G-code simulators. Teaching the applied milling and turning practices is the main deliverable of the course with a required term project which is focused to service learning concept. Student teams formed in the middle of the semester design, simulate, and machine a functional service learning product using the departmental computers, simulators, and CNC machines for their project. The feedback provided by the project students presents a number of progresses on the attainment of the ABET Student Outcomes. This paper reports the development and implementation aspects of this course.

1. Introduction

In Fall 2022, a required subtractive manufacturing course has been improved with a term project focused to service learning. The intention was to develop and implement practices tied to service learning and enhance the course students' learning and success by implementing a service learning – focused term project. Service Learning is a teaching and learning approach that connects academic course to community-based problem solving practices [1]. Service Learning has been proven as a successful student-centered learning activity in a high number of Engineering and Technology Courses [2][3]. It has been proven that Service Learning has a positive effect on students' learning and success in a number of ways by

- providing hands-on use of skills and knowledge that increases the grasp of course learning outcomes,
- accommodating different learning styles to increase students' learning,
- providing opportunities to apply what students have learned in the real world, and
- helping students prepare for the job market.

The course was assessed and evaluated by using the standard IDEA course evaluation to measure the success rate of the course students in ABET-ETAC Student Outcomes [4][5]. The results of the Evaluation of ABET-ETAC Student Outcomes 1, 2, 3, and 5 [6][7] are presented in the paper.

2. Definition of the Curricular Terms

This paper uses several terms such as subtractive manufacturing, CNC, ABET, service learning, and assessment. The following section provides an explanation of each concept used in the paper.

2.1. Subtractive Manufacturing

Subtractive manufacturing is one of the oldest production technologies. The traditional name of the technology is Machining Process. After the popularity of Additive Manufacturing, the use of Subtractive Manufacturing term is growing [8][9][10]. In general, manufactured parts could be a block of, for example, metal, plastic, or wood. A milling machine cutting/hollowing out a piece of metal or plastic is an example of subtractive manufacturing. Subtractive manufacturing by manually cutting the material is also possible. In fact, before the industrial revolution, that was how most of it was done [11][12].

Subtractive Manufacturing can also be defined as traditional manufacturing or machining, involves creating 3D objects by removing material from a solid block or raw material through cutting, grinding, milling, or drilling. This process results in highly precise and accurate functional parts and components for various industries, such as aerospace, automotive, defense, and medical devices, as well as prototypes and custom products in small quantities. Well-established for many years, Subtractive Manufacturing has a broad range of tools and machines for various materials, including metals, plastics, composites, and ceramics. However, it has limitations such as requiring specialized tools and machinery and producing a large amount of waste material.

2.2. CNC

CNC, short for Computer Numeric Control, is a type of automated manufacturing process using computer-controlled machines such as lathes, mills, routers, and plasma cutters [13][14]. The CNC machines use a computer program, known as G-code, to execute precise and consistent production of parts with high accuracy and repeatability. The process begins with creating a digital design, which is then transformed into G-code for the CNC machine to follow. This code controls the machine's movements, such as cutting speed, direction, and location. The result is the final product.

Compared to traditional manufacturing methods, CNC machines offer several advantages including improved accuracy and consistency, greater efficiency, less waste, and the capability to produce complex parts that would be challenging or impossible to produce manually.

2.3. ABET

ABET (Accreditation Board for Engineering and Technology) is a non-profit, non-government organization responsible for accrediting college and university programs in the areas of applied science, computing, engineering, and engineering technology. ABET accreditation is considered a symbol of quality and assurance that the program has met strict standards set by the engineering and technology industry [15][16].

ABET assesses programs based on curriculum, faculty, facilities, and other resources, as well as students' outcomes and achievements. The accreditation process aims to encourage continuous improvement in engineering and technology education and ensure that graduates have the necessary knowledge and skills to meet industry and society's evolving needs.

ABET accreditation holds significant value for students, faculty, and programs, as it proves that the program has met rigorous standards and is dedicated to providing quality education. Accreditation by ABET also offers recognition and professional development opportunities for graduates.

2.4. Service Learning

Service learning is an educational method that blends community service with academic instruction, reflection on the service experience, and connecting it to personal and social growth. Its aim is to offer students practical opportunities to use their knowledge, skills, and values to tackle real-world issues, while fostering a sense of civic duty, empathy, and self-improvement [1].

Examples of service learning projects include designing and building a toy for a disabled kid, fabricating laboratory equipment for a science teacher, developing a playground for an under-served community, and participating in an environmental clean-up initiative. Service learning can be integrated into various academic fields, including but not limited to, education, psychology, sociology, public health, and environmental studies.

Service learning offers numerous benefits to students, including developing leadership skills, promoting civic engagement, and gaining hands-on experience in their field of study. It also positively impacts the community by addressing local needs and fostering relationships between students and community members.

2.5. Assessment

The evaluation and measurement of the quality, performance, and effectiveness of an educational program or institution is referred to as assessment. In the context of accreditation, it is utilized to assess whether the standards and criteria set by accrediting bodies, such as ABET, have been met by the program or institution .

The accreditation assessment process involves gathering and examining data on various aspects of the program or institution, including its curriculum, faculty, facilities, student outcomes, and more. This information is then used to make informed decisions about the program or institution's quality and effectiveness and to determine its compliance with the standards set by the accrediting body.

Assessment may take place through self-study, peer review, or site visits and may involve input from students, faculty, alumni, and community members. Its objective is to identify the program or institution's strengths and weaknesses and to drive continuous improvement and quality assurance.

Assessment is crucial in the accreditation process as it provides a way to evaluate the quality and effectiveness of educational programs and institutions and ensures they meet the needs of students, industry, and society.

3. Engineering Enhancements for Student-Centered Learning @ Tech (ESCL@Te)

Numerous engineering educators have noted that student-focused learning activities enhance student involvement and result in improved knowledge retention and future success. Although faculty members acknowledge the benefits of student-centered learning, they often face constraints on the time needed to develop and implement these activities throughout their courses. To address this challenge, the College of Engineering at Tennessee Tech University launched a remarkable initiative in 2022: Engineering Enhancements for Student-Centered Learning @ Tech (ESCL@Te). The aim of this initiative is to equip faculty with the tools and resources required to incorporate meaningful and lasting student-centered teaching methods into their engineering courses.

The ESCL@Te initiative called for proposals to identify one or more engineering courses where best-practice, student-centered learning methods could be established, sustained, and improved in future offerings. The initiative provided financial assistance, additional administrative support, course relief, and travel funding as necessary to facilitate the course restructuring. The goal was to enhance courses that would have a substantial, wide-ranging, and enduring effect on student learning for the majority of students in one or more engineering programs, at both the undergraduate and graduate level. The ESCL@Te program provided funding to accomplish the deliverables of this innovative course project.

4. Service Learning based Subtractive Manufacturing Course

In the fall of 2022, the Junior level course, CNC Machining Practices offered for the Engineering Technology students, underwent an upgrade that incorporated a service learning component. This upgrade process was held with a support provided by the ESCL@Te program. The objective of this course revision was to aid students in acquiring practical skills through service learning projects. Midway through the semester, student teams were formed and tasked with designing and creating various types of original germ tools [17]. Capitalizing on the heightened

awareness of germs during the COVID-19 pandemic, the teams devised a number of innovative and useful germ tools that can be used in everyday life. Figure 1 presents a number of germ tools developed and prototyped by the course students at the begging of their term projects.

Figure 1: Germ Tools developed and prototyped by the CNC Machining Practices course students at the beginning of their term projects.

Student teams have designed and machined several germ tools using CNC Workshop and Fusion 360 software tools. Then, they were CNC-machined with the use of FADAL Milling machine. The core of the practice was to help course students gain a number of professional skills in design, analysis, and manufacturing. Several team times, discussion opportunities, and prototype cuts were provided so that the teams come up with cutting-edge designed and manufactured parts. One sample design and machined piece are shown in Figure 2.

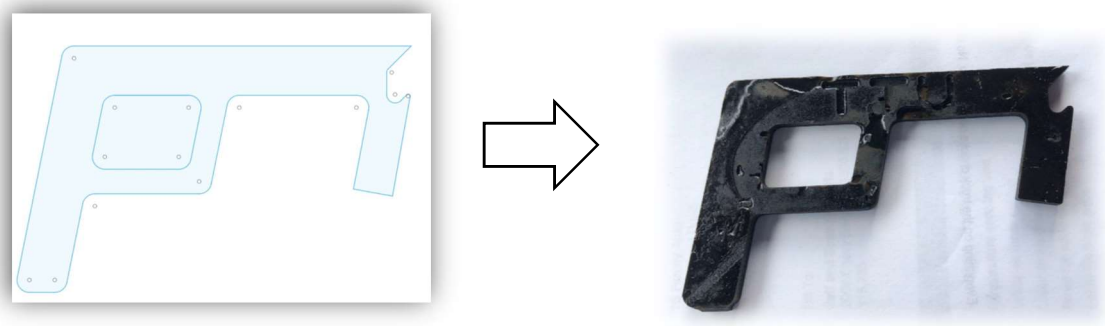


Figure 2: Germ Tool sample designed and machined with the software tools and CNC machines at Tennessee Tech University

During the development and implementation stages of the course, the following ABET Student Outcomes were the focus in lectures, laboratories, and course assessments.

The Engineering Technology program will produce students who show an ability to:

1. apply knowledge, techniques, skills and modern tools of mathematics, science, engineering, and technology to solve broadly-defined engineering problems appropriate to the discipline;

2. design systems, components, or processes meeting specified needs for broadly-defined engineering problems appropriate to the discipline;
3. apply written, oral, and graphical communication in broadly-defined technical and non-technical environments; and an ability to identify and use appropriate technical literature;
5. function effectively as a member as well as a leader on technical teams.

The feedback received from the course students as a result of the IDEA survey provided that the service learning practice as part of the term projects in the CNC Machining Practices was liked. Table 1 shows the quantitative representation of the survey results. Students did not provide any qualitative comments.

The focus of the course is on Student Outcomes 1, 2, 3, and 5. The results of the survey showed that the course students provided positive feedback about their satisfaction on attaining these outcomes.

Table 1: Quantitative data provided by the CNC Machining Practices course students

Question	No Apparent Progress	Slight Progress	Moderate Progress	Substantial Progress	Exceptional Progress	Mean	Standard Deviation
Student Outcome 1: Learning to *apply* course material (to improve thinking, problem solving, and decisions)				75%	25%	4.25	0.43
Student Outcome 2: Developing specific skills, competencies, and points of view needed by professionals in the field most closely related to this course				75%	25%	4.25	0.43
Student Outcome 3: Developing skill in expressing myself orally or in writing			25%	75%		3.75	0.43
Student Outcome 5: Acquiring skills in working with others as a member of a team				50%	50%	4.5	0.5

The data collected in Fall 2022 was also compared to the course data in Spring 2022. Table 2 shows the difference between these two semesters. Fall 2022 data is shown in green while Spring 2022 data is shown in purple.

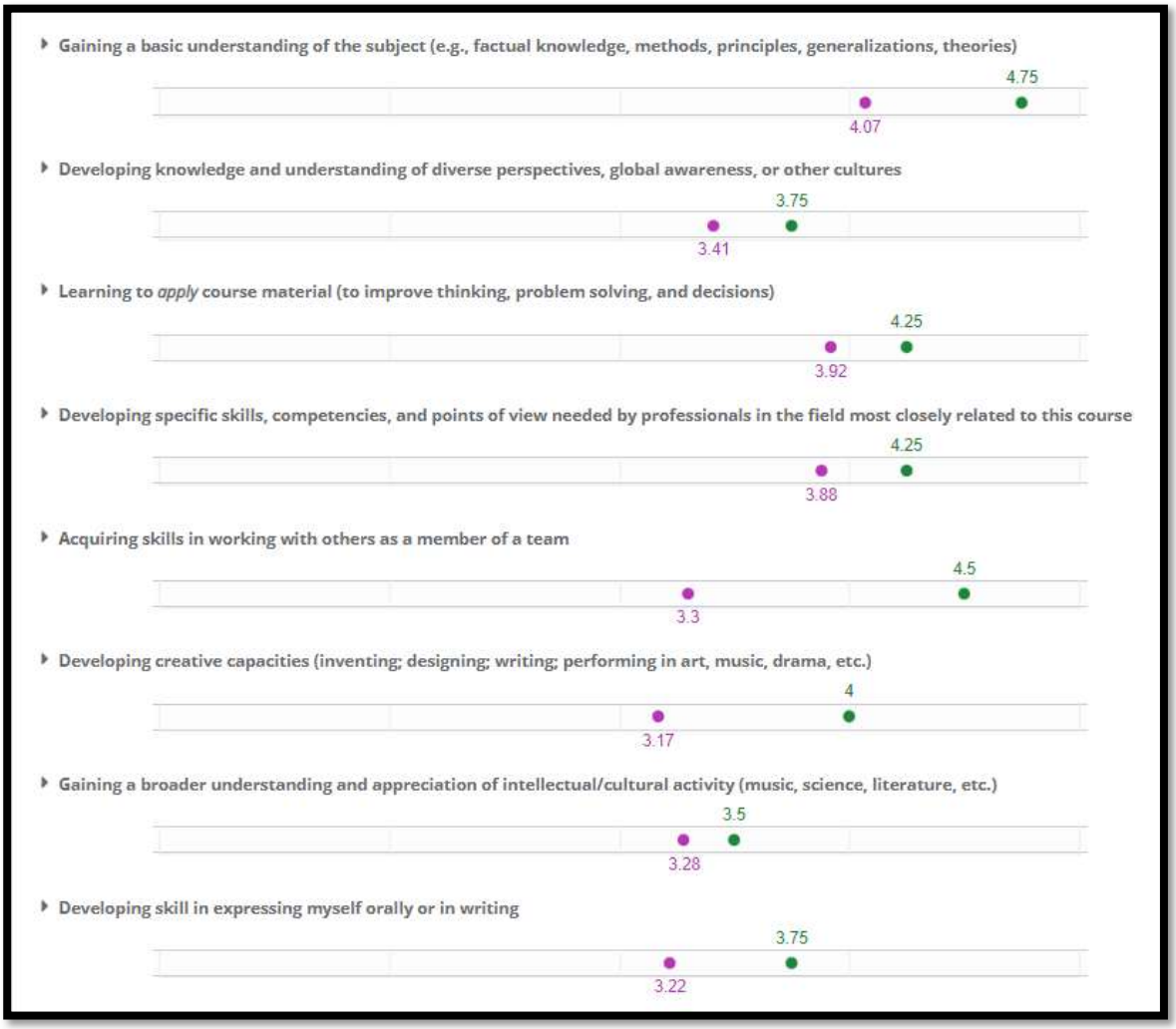
As it can be seen from Table 2, it is evident that the service learning active learning practice was very well liked by the students in all categories. The course students provided higher satisfaction ratings compared to the ratings provided by the Spring 2022 students.

5. Conclusions

Service learning is an educational approach that combines community service with instructional/laboratory activities and reflective components, enhancing the overall learning experience. This approach has been widely adopted in numerous engineering and technology courses, with great success. Recent studies have shown that it can also be applied to a number of

manufacturing courses, where students have expressed a positive preference for learning through service learning projects. The study presented in this paper provides another best practice from a subtractive manufacturing course by advancing the design and machining of a versatile germ tool. The results of a student survey conducted for this purpose from the subtractive manufacturing course were compared to data from the previous semester. It was observed that there was a significant improvement in student learning and the attainment of ABET Student Outcomes, due to the integration of service learning into course term projects.

Table 2: IDEA Survey results of the MET3060 course for Spring 2022 and Fall 2022



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