Developing an Advanced Manufacturing Course for Mechanical Engineering and Mechanical Engineering Technology BS Programs

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Abstract

This paper discusses the development of a contemporary advanced manufacturing course to be offered into the B.S. in Mechanical Engineering (BSME) and the B.S. in Mechanical Engineering Technology (BSMET) programs to meet the needs of Northeast Indiana industry. Details will be provided on the curriculum design, indicating how this new course will provide students with basic understanding on applications of contemporary machining processes, including hands-on activities. Also, implications on mechanical design aspects will be addressed to broaden students' perspectives on processes and optimization.

1. Introduction

Many manufacturing companies are hosted by the Northeast Indiana region, and they produce a variety of high value-added products; they are companies such as General Motors, Zimmer Biomet, Steel Dynamics BAE Systems, BF Goodrich, and others mainly dedicated to mechanical manufacturing and auto-parts.

The region's industry requirements for engineering graduates were assessed by surveys conducted by Indiana Tech and distributed to manufacturers and other businesses in the region, as well as to graduating students with a record of internships done in the area. As for the employers, 84% respondents stated that they have manufacturing or related activities as their primary business, 63% employ up to 500 people (63.16%) and 36.84% employ between 1,001 and 10,000 people (Figures 1 and 2).

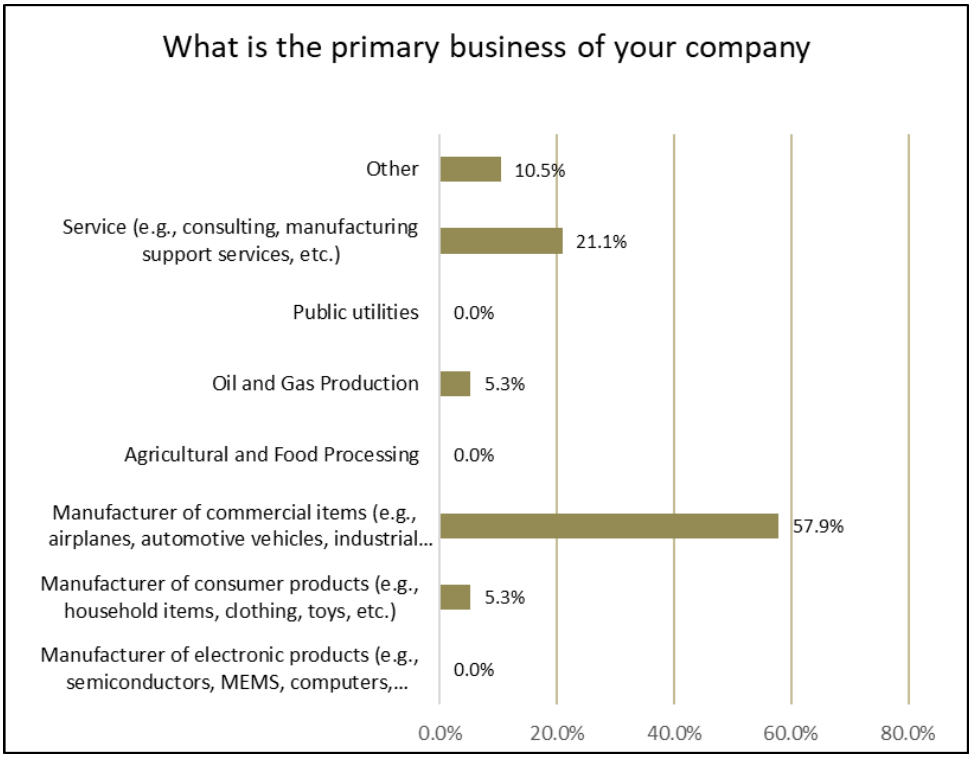

Fig. 1. Region's employers' primary business.

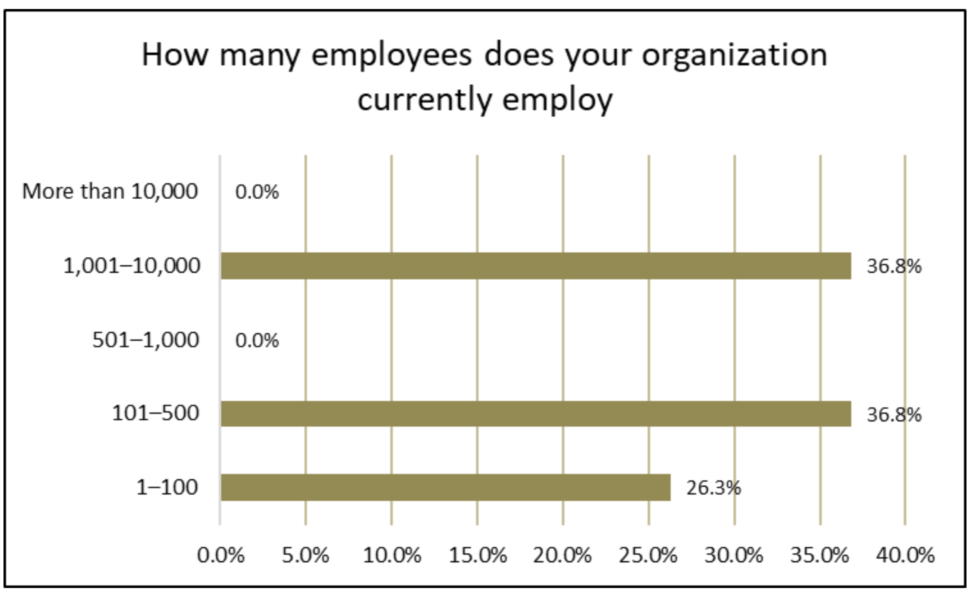

Fig. 2. Current employment by companies in the region.

According to the surveys conducted among senior students, 25% of the students declared that their new jobs are manufacturing related in the Spring 2021 and 66.67% in the Spring 2022 semester (Figure 3).

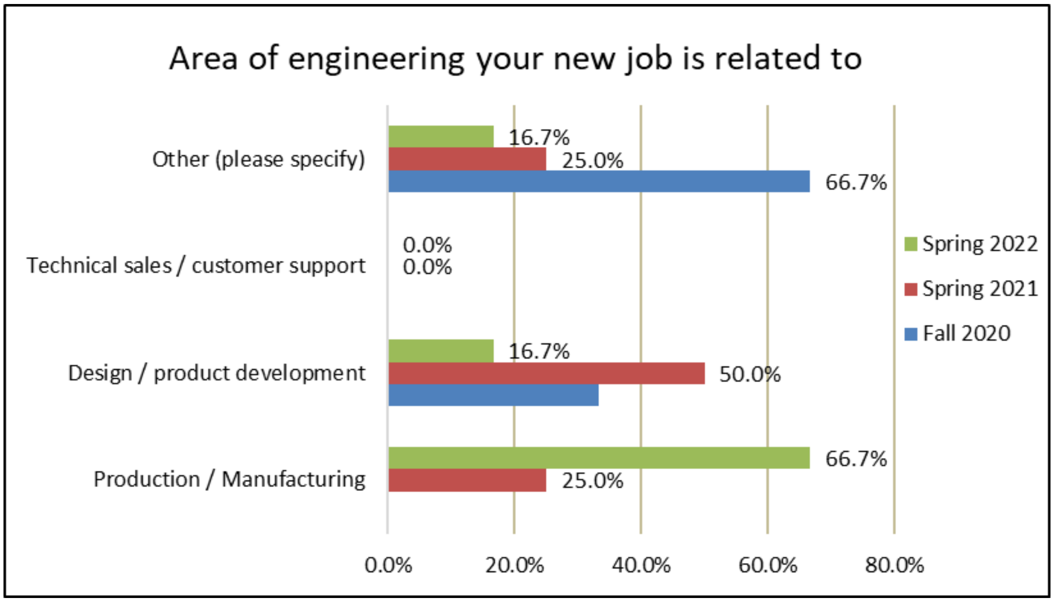

Fig. 3. New jobs, area of engineering.

Also, 57.14% of the students had internship experiences related to manufacturing in the Fall 2020 semester, 42.86% and 75% in the Spring 2021 and Spring 2022 semesters respectively (Figure 4).

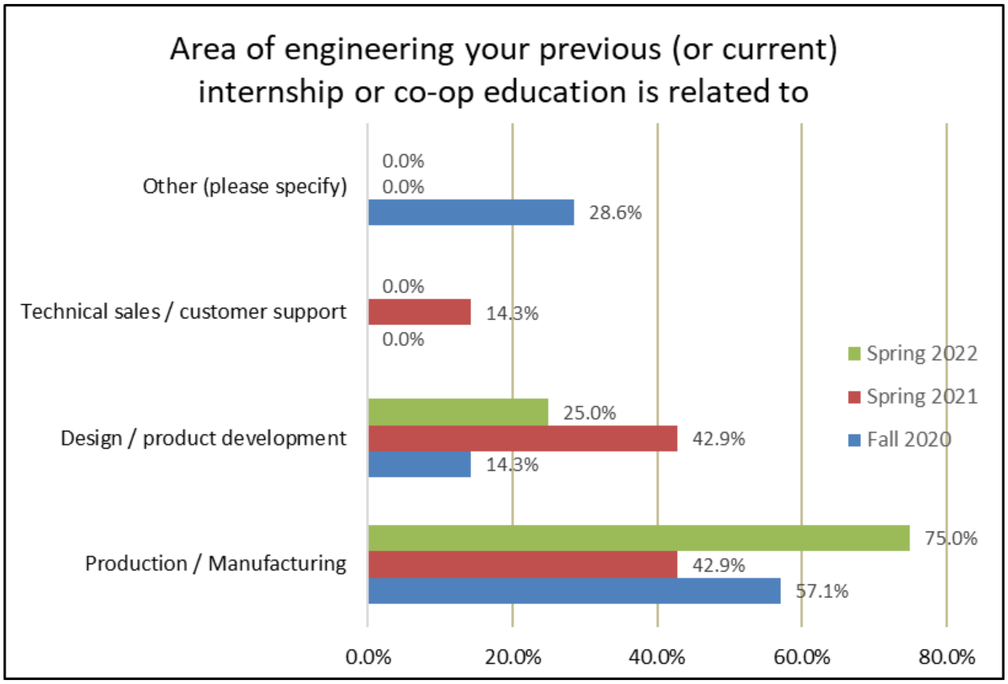

Fig. 4. Co-ops or internships, area of engineering

Students' opinions on how the Mechanical Engineering program prepared them to perform in their current career are neutral/somewhat related in 49.95% of the answers in Fall 2020, 30% and 62.50% in Spring 2021 and Spring 2022 semesters, respectively (Figure 5).

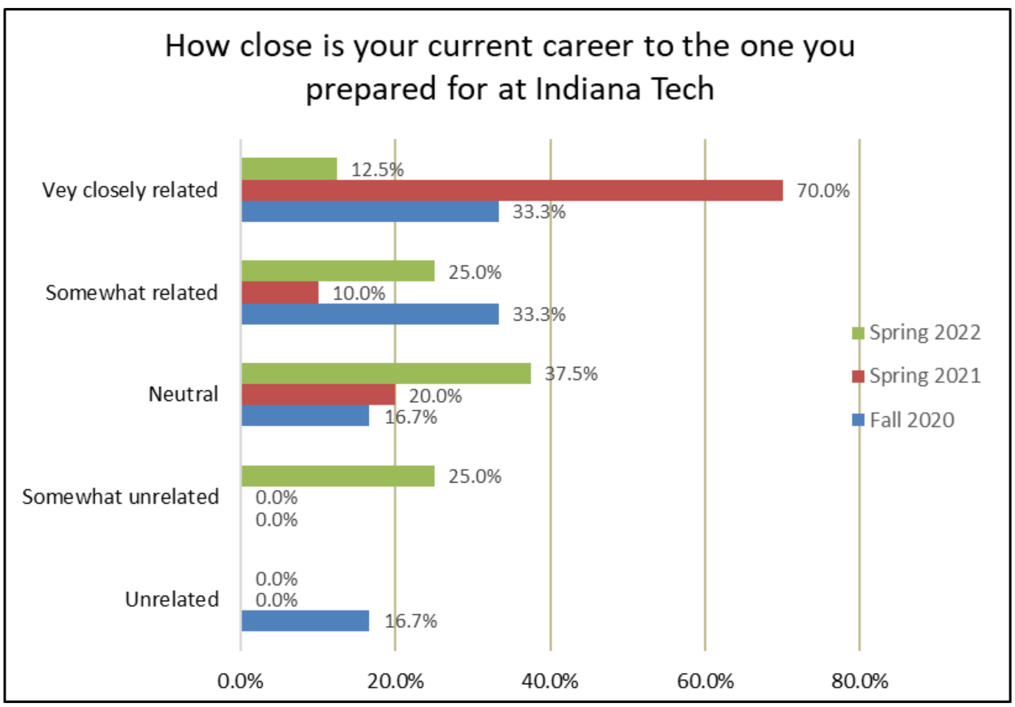

Fig. 5. Students' opinions on how well prepared they are for their careers.

Mechanical engineering graduates work in construction, energy, automotive, food production, materials, medicine, sales, transportation, etc. [1] what makes it one of the most diverse of the engineering disciplines and encompasses the utilities, manufacturing, construction and medical sectors. Most schools currently offering mechanical engineering or mechanical engineering technology programs include in their curriculum 1 to 3 credit hours of courses in general manufacturing processes, offering a broad view in this subject, but very limited exposure to modern machining, which represents a competency gap considering the profile of most of the employers in the region, as data from the surveys clearly shows. Mechanical Engineering and Industrial Engineering are often most strongly associated with manufacturing, and it represents a strategic direction and opportunity for engineering education to pursue [2].

With the rapid changes in technology, there is great demand for automotive and mechanical engineers who have a strong background in STEM, especially with 3D printing and other technologies [3].

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2. Certificate Programs

With evolution of technologies and the need to upskilling and reskilling of the workforce, it is necessary for higher education institutions to seek ways to give students the skills and knowledge they need right now, as observed by Levine and Van Pelt [4]. Certificates and Micro-credentials are the means by which institutions are addressing that requirement.

Department's Economic Development Administration (EDA) awarded a $1.5 million grant to Indiana Tech to purchase technical equipment to support engineering- and manufacturing-related certification programs. This grant is funded by the American Rescue Plan [5]. The supported programs are:

- Programmable Logic Controller Certificate
- Cybersecurity & Data Analytics
- Additive Manufacturing / 3D Printing Certificate
- Automation Certificate
- Cybersecurity & Information Management
- Artificial Intelligence Certificate
- Printed Circuit Board Design Certificate

The Additive Manufacturing Certificate will be the focus of this paper.

3. Additive Manufacturing / 3D Printing certificate

ASTM has defined additive manufacturing (AM) as "a process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies. Synonyms: additive fabrication, additive processes, additive techniques, additive layer manufacturing, layer manufacturing, and freeform fabrication" [6].
The term additive manufacturing is not new. To the contrary, it has actually been around for several decades, but until recently the technology was not mature enough to make it a practical

proposition. Although the terms "3D printing" and "rapid prototyping" are used interchangeably in reference to additive manufacturing, each one is actually a process within the additive manufacturing realm.

The ability to effectively produce complex geometries using 3D printing processes and the inherent benefits in design have an extraordinarily strong appeal in industry, who sees many opportunities to improve efficiencies and optimize their manufacturing processes.

The proposed curriculum is depicted in Table 1.

Table 1. Additive manufacturing curriculum.

Courses	Cred. Hours	Pre-req / co-req
EGR 1710 - Engineering Graphics and Design	3	MA 1010
EGR 2710 - GD&T	3	EGR 3600 with a grade C or better
MET 2800 - Introduction to Machining	3	MA 1055 with a grade of C or higher; EGR 2600. Co-requisite(s): EGR 2710
EM 2900 - Advanced Machining (*)	3	MET 2800
EM 3100 - Additive Manufacturing Processes (*)	3	EM 2900
EM 3200 - Advanced Additive Manufacturing (*)	3	EM 3100
Total Credits Required	**18**	

(*) New courses

The courses EGR 1710, EGR 2710 and MET 2800 are currently part of the Mechanical Engineering Technology program and they will lay the foundation needed for students to progress towards more complex subjects. The courses EM 2900, EM 3100 and EM 3200 are new and will be focused on advanced manufacturing processes related topics. This program will not require approval from the Higher Learning Commission (HLC) as no more than 50% of the courses will be specifically developed [7].

These courses will be offered as technical electives for the mechanical engineering and mechanical engineering technology programs and will be prescribed by advisors based on students' career expectations and/or professional experience.

3.1.New courses

The new courses will cover the following subjects:

3.1.1. EM 2900 Advanced Machining:

- Safety and Maintenance
- CAM Software Operations

- CNC Mill Set-up
- Part Modifications on CNC Mill
- CNC Mill Operations
- CNC Mill Programming
- CNC Lathe Set-up
- Part Modifications on CNC Lathe
- CNC Lathe Programming

3.1.2. EM 3100 Additive Manufacturing processes:

- Review of General Manufacturing
- Extrusion-Based Deposition
- Fused Filament Fabrication, Continuous Filament Fabrication (composite materials)
- Metal fused filament fabrication
- 3D Meshing Optimization; Open-Source / 3D Model Sharing
- Additive Manufacturing for Industrial Applications
- Additive Manufacturing for Research Applications

3.1.3. EM 3200 Advanced Additive Manufacturing:
This course will be developed with technical support from EOS North America [8] and will focus the direct metal laser solidification (DMLS) technology. It will cover the following areas:

- Application Engineering Metal
- Data Preparation technology.

4. Equipment and facilities

The laboratory equipment for the programs is being acquired with funds from the EDA grant [5] awarded to Indiana Tech as well as a donation from a graduate of the mechanical engineering program. The equipment selected is representative of the most common 3D printing processes for polymers and metals. The list is depicted in Table 2

Table 2. Equipment for the additive manufacturing laboratory.

Type		Specifications
3D Prinitng Equipment	3D Scanner	EinScan Pro HD Handheld 3D Scanner
	3D Printer Large Bed (Rapid Prototyping)	Raise 3D Pro3 Plus 12 X 12 X 12 in.
	Carbon Fiber 3D Printer (2x)	Markforged X7
	Metal Sintering 3D Printer (2x)	Markforged Metal X
	Direct Metal Laser Sintering technology	EOS M290 Laser Sintering
	Selective Laser Sintering	EOS P110 Laser Sintering
Auxiliary Equipment	Heat Treatment Furnace	N/A
	Abrasive Blast Cabinet	N/A
	Metal Cutting Bandsaw	N/A

The mechanical engineering and mechanical engineering technology programs are housed in the Zollner Engineering Center, which is under an ongoing expansion project, representing an Indiana tech investment of $21.5 million. This project is comprised of the addition of 30,000 square feet and renovation of existing 40,000 square feet and is scheduled to be concluded by the Summer of 2023. In addition to other improvements, the areas designated as “Additive Manufacturing Laboratory” is being added. This space, along with the existing labs will provide the necessary support to the new certificate programs.

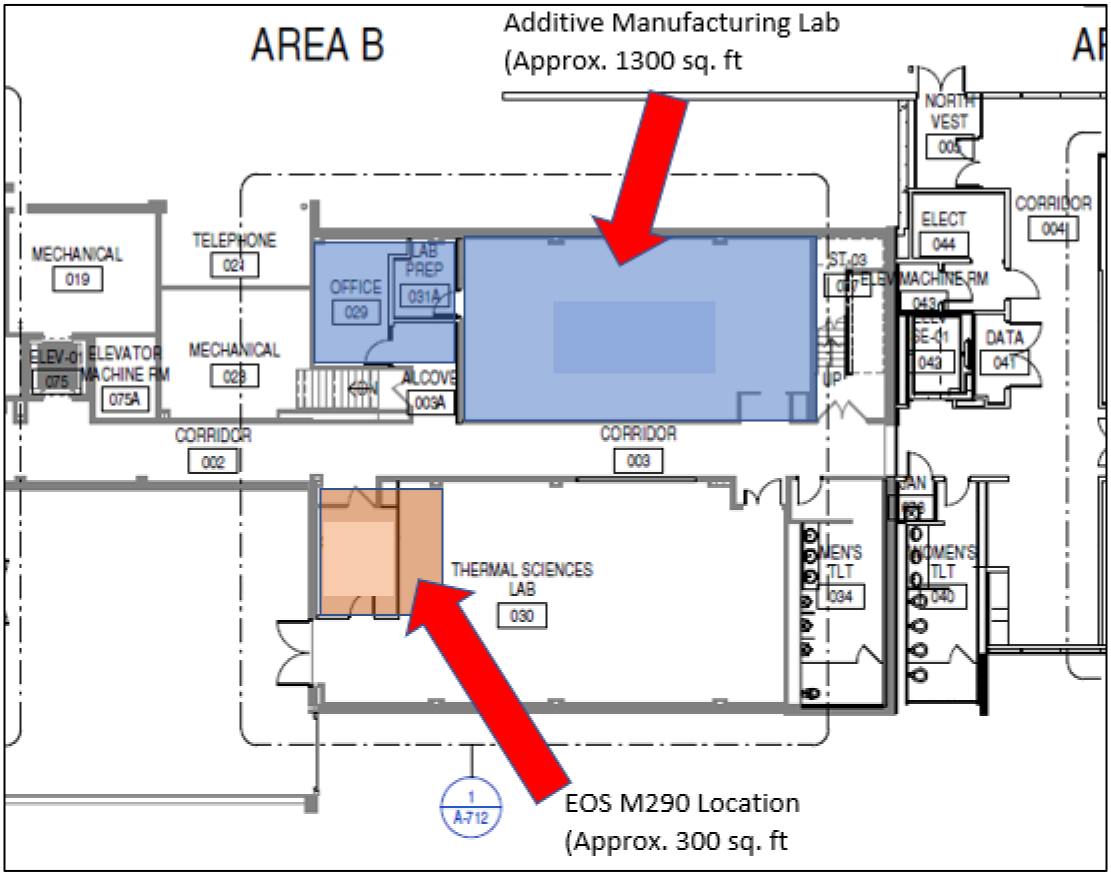

Fig. 6. Location of the additive manufacturing lab in the Zollner Engineering Center Expansion Project

5. Conclusion

Northern Indiana economy is driven mainly by manufacturing industries and the availability of adequately trained individuals is paramount to fulfill their human resources needs. The new courses offered in the Additive Manufacturing/3D Printing Certificate program will provide students with the necessary exposure to contemporary mechanical manufacturing processes. As data have shown, in the NE Indiana region most of graduates will land in careers related to mechanical manufacturing. That knowledge can expedite the qualification of individuals to perform in their respective areas, reducing the need of job training programs to build and/or maintain job competency. Implications on mechanical design are compelling reasons why educational institutions should invest in their manufacturing curricula [9]. These courses also will provide the tools necessary for graduates to assume leadership positions faster, enabling them to have a significant impact in industry.

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Biographies

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