Meeting the Needs of Industry via a Computer Numerical Control Concentration in a Mechanical Engineering Technology Curricula

ABSTRACT

Recent engineering education research has concluded that most engineering curricula do not promote attainment of many skills desired in practicing engineers. One such skill required by a segment of industry is proficiency in computer numerical control (CNC) programming. Based on feedback from Northern Michigan University's Engineering Technology Department's Industrial Advisory Board, the department implemented a CNC concentration for the Mechanical Engineering Technology bachelor's degree program in 2010. The CNC concentration is one of five concentration choices the students have, and they take these classes primarily in their junior and senior years. The CNC concentration consists of 14 credits focused on CNC programming and other manufacturing topics. This concentration complements a strong core of engineering fundamentals courses.

Student outcomes since the inception of the CNC concentration have been studied. It has been determined that the CNC concentration is one of the more popular choices among students, with many of the graduates utilizing CNC programming skills in their entry level positions. A higher percentage of graduates with the CNC concentration were employed in the engineering field 6 months after graduation, and with higher average salaries, than their counterparts with other concentrations in the same degree program. Additionally, there is strong anecdotal evidence that once students with this knowledge got out in the workforce, it created additional demand from employers that were pleased in how the students were able to contribute immediately upon hire.

INTRODUCTION

Recent engineering education research has suggested that most engineering curricula does not promote attainment of many characteristics desired in practicing engineers [1][2], especially that in the skilled manufacturing field [3]. One skill set that has been identified as a need by local industry is computer numerical control (CNC) programming. This need was originally identified by the Northern Michigan University's (NMU) Industrial Advisory Board, and has been reinforced through feedback of employers of graduates that have the requisite technical knowledge to do this type of work.

This need has also been identified by the United States Department of Labor's Bureau of Labor Statistics, which identified that the number of people employed as CNC Programmers is expected to increase by 16.3% over the 10 year period of 2016-2026. This far exceeds the both the estimated growth for all occupations over this time period (7.4%), as well as for Mechanical Engineers (8.8%) [4]. As can be seen in Figure 1, employment of CNC programmers is concentrated nationally in the upper Midwest. With NMU'a position as a regional Midwestern university, it is

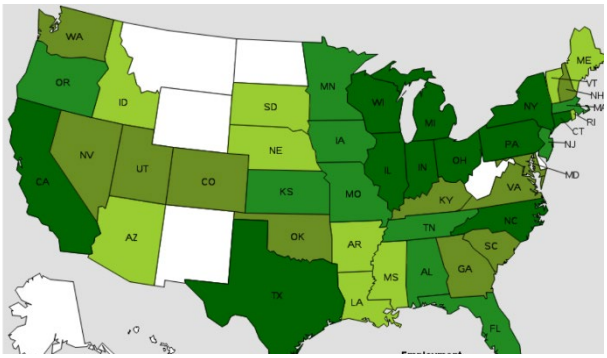

Figure 1: Employment of Computer Numerical Control Programmers, metal and plastic, by state, May 2017 [5].

geographically perfectly positioned to serve this demand.

While the role of a CNC programmer has historically been viewed as a vocational education-based skill, the advent of Computer Automated Manufacturing (CAM) has increased the technical skills required of many CNC programmers [6]. Additionally, in Michigan, 46% of employees in the manufacturing sector work for small companies [7]. Many of these small companies need their CNC programmers to have multiple skill sets. While in the past, the secondary skill set of CNC programmers has been machinist, the secondary skill set is transitioning to that of engineer.

Based on suggestions from NMU's Industrial Advisory Board, as well as feedback from numerous regional employers of engineering technology graduates, the engineering technology department made a significant investment into a CNC lab, and the hiring of a dedicated CNC instructor. This lab and instructor support both a 1-year certificate and a 2-year associate degree program in Computer Numerical Control Technology. However, the focus of this paper is the 14 credit CNC concentration in the Mechanical Engineering Technology bachelor's degree program.

METHOD

The Mechanical Engineering Technology curriculum is formatted such that the student must select a 14-credit concentration, which focuses the students' knowledge in a particular area of mechanical engineering. Concentration choices are:

- Mechanical Engineering Design
- Mechatronics
- Industrial Management
- CNC Technology
- Alternative Energy

The CNC Technology Concentration, which is the focus of this paper, is a collection of the following courses:

- DD 103 Geometric Dimensioning and Tolerancing (2 credit)
- IT 420 Quality Control (3 credit)
- MF 233 Numerical Control (4 credit)
- MF 235 Computer Numerical Control (3 credit)
- MF 263 Advanced CNC Operations (4 credit)
- Any DD, ET, IT, MET or MF prefix course (1-4 credits)

The students must complete 14 credits from the above list. Students are encouraged to select a concentration by the first semester of their junior year, so that they have a minimum of 3 semesters in which to fit the concentration classes into their class schedule. Prerequisites for the above classes; MF 134 – Manufacturing Processes (pre-requisite for all the MF classes), and MA 171 Statistics (pre-requisite for the Quality Control class), would typically be taken in the freshman year. The core of the CNC concentration are the three MF classes which focus on CNC programming of mills and lathes.

The first class of the sequence is MF233. This course is broken into two sections; which are CNC programming for a vertical mill, and CNC programming for a lathe. Both of these topics review manual G&M code programming, as well as CAM programming utilizing Mastercam in conjunction with Solidworks 3D modeling software. One of the highlights of this course is a project in which the student must complete a project of some type. The projects are usually a service to the community or university. Examples of projects completed in MF 233 are fluid

transfer valves for the university power plant, chess sets for the chess club, and parts for the SAE Baja Club vehicle.

The next classes in the CNC sequence, MF 235 and MF 263, do not need to be taken in a particular order, however, MF 233 is a prerequisite for both of them. MF 235 is an industry-university collaboration between NMU and RTI Surgical, a local manufacturer of precision medical devices. This class is taught by a manufacturing engineer from RTI Surgical. The class actually occurs on-site at RTI. One element of this class is programming and utilization of Swiss Turn Lathes, which are commonly used in volume production of turned products.

The remaining class in the CNC sequence is MF 263 which, like MF 233, is taught out of the Northern Michigan University CNC lab. The class expands upon the basics of CNC turning and mill operations as well as more advanced use of Mastercam. The highlight of the class is project based, in which the students are tasked with manufacturing parts of an assembly designed by students in the MET320 Mechanical Design course. The students from the design class are tasked with designing a simple assembly that performs a specified function. Previous design tasks have included small machinists vice and toggle clamps. The design student is responsible for generating a complete set of manufacturing prints and solid models of their design. Each design student is matched with a group of two or three MF 263 students, who are responsible for manufacturing the parts designed by the engineering student. This type of collaboration closely simulates the design engineer working with the manufacturing engineer in determining how a part is best produced and taking the project to completion by manufacturing and assembly of that part [8].

The remaining courses in the concentration, Geometric Dimensioning and Tolerancing, and Quality Control, are taken by the students based on interest and scheduling. Both courses are very relevant to CNC manufacturing. Students are also allowed 1-4 technical electives to be used in the concentration, this option is most often used by transfer students who had technical transfer credits that did not fit anywhere else at NMU.

The CNC Lab at NMU is the lab used to support MF 233 and MF 263. It also supports many senior projects, SAE Baja Club projects, and other university/industry projects. The lab consists of two Hass VF-1 vertical machining centers, a Hass SL-10 turning center, four Haas TL-2 turning centers, 7 Hass CSMD training displays, and four desktop computers loaded with Solidworks and Mastercam (see pictures below). Students are also able to load Solidworks and Mastercam on their university-issued laptop computers to enable them to work remotely on their projects.

Figure 2: Picture of CNC mills at NMU CNC Lab.

Figure 3: Picture of Hass CSMD trainers and desktop computers in NMU CNC Lab.

RESULTS

Due to an internal outcomes assessment initiative, employment and salary information for graduates from the Mechanical Engineering Technology degree program is tracked. This is done in two ways. During the last couple weeks of a student's last semester at NMU, they are required to participate in an exit interview with the Department Head. During this interview, students are asked if they have employment lined up, and if so, what is the position and salary. Answers to these questions are optional, but all students freely share employment status, and about half share salary information. Methods of future communication with the student is also attained. If the student was not employed at graduation, then 6 months after graduation, an attempt is made to contact the student by the department secretary. While occasionally there is a student that is not able to be contacted, nearly all students are successfully contacted. Additionally, due to the considerable time spent together in class and the lab, the faculty member that teaches the CNC classes develops close personal relationships with the students in this concentration. His personal knowledge of the students and their employment was also used in the below analysis.

The first Mechanical Engineering Technology students to graduate with a concentration in CNC Technology graduated in academic year 2011-2012. The data presented below is from that year through academic year 2017-2018. Over this time period, there were a total of 78 graduates with the MET degree and a concentration. Overall, 88% of these graduates were employed in their field within 6 months of graduation. However, as shown in Figure 4, graduates with the CNC concentration have a much higher likelihood of employment than graduates with the other concentrations.

	# Graduates	# Employed	% Employed
Total	78	69	88%
With CNC Concentration	19	18	95%
All Other Concentrations	59	51	86%

Figure 4: Table showing # of NMU graduates with MET degree by concentration along with employment (or continuing education) at 6 months after graduation.

Additionally, of the 18 employed graduates with a CNC concentration, 12 of them cite CNC programming as a responsibility of their position. Two other cite their manufacturing and CNC knowledge as critical in their role as design engineers, even though they do not CNC program on a regular basis. Previous research has indicated that the more closely aligned the training is with the job function, the higher the job satisfaction [9][10]. So many graduates with the CNC concentration, may very well have the auxiliary benefit of additional job satisfaction.

Starting salaries of graduates was also examined. Though the data is not comprehensive, only about half of the graduates choose to share their starting salary, the CNC graduates had a higher average starting salary than those graduates with another concentration (Figure 5).

	# Employed Graduates	# Providing Salary Info	Mean Starting Salary
With CNC Concentration	18	8	$54,900
All Other Concentrations	51	27	$53,000

Figure 5: Table showing average starting salary of NMU MET graduates by concentration.

Based on the large number of CNC concentration graduates using CNC in their engineering positions, a higher percentage of employed graduates, and higher average starting salaries, it can be concluded that attaining the CNC concentration with the MET degree is meeting a demand of industry. It also can be concluded that having the CNC concentration improved the MET graduate's employability over having one of the other concentrations.

There is some additional, anecdotal, evidence to support the above conclusions. One of the spring 2012 graduate with the CNC concentration went to work for a particular employer and one of their primary responsibilities was CNC programming. In the spring of 2016, this particular company hired two additional MET students that had the CNC concentration. These are the only MET students that this particular company has hired. In another instance, the owner of a small company that had hired a CNC concentration MET student told the CNC faculty member that when he needs another engineer, he will be looking for an NMU MET student with the CNC concentration. He explained that the combination of engineering fundamentals, design/CAD experience, and CNC programming knowledge made for a flexible employee that contributed on the job immediately and was much more valuable to him than engineers hired out of other engineering programs.

RECOMMENDATIONS

Employment trends indicate that CNC programming job positions over the next 10 years will be growing at a rate much higher than all occupations as well as those of mechanical engineers. Experiences of NMU MET graduates with a CNC concentration indicate that they are in higher demand than a typical MET degree graduate. Northern Michigan University is the only university in the upper Midwest (Michigan, Wisconsin, Minnesota, and Illinois) to offer more than one class of CNC-based topics in conjunction with either a Mechanical Engineering Technology or Manufacturing Engineering Technology bachelor's degree program.

All of the above couple to indicate a significant industrial need for CNC programming expertise coupled with an engineering background, along with a lack of supply to fill this need. The Mechanical Engineering Technology, or Manufacturing Engineering Technology, degree programs are well suited to meet this demand. Recommendations for engineering technology departments looking to fill this need are as follows:

- Survey your industrial advisory committee, Chamber of Commerce, or local business's themselves, to determine the local or regional need.
- Explore funding opportunities for the required equipment. This could include a partnership with local industry, state-based initiatives for technology education, or internal university funding.
- Hire a faculty member that has industrial CNC programming experience, preferably along with CAD and CAM software experience.

- Develop a curriculum, possibly along with an industrial partner.
- Implement the curriculum and start producing graduates!

CONCLUSION

Through the literature, it has been established that there is a need for CNC programmers in the US manufacturing sector. It has also been established that having CNC programming skills, coupled with engineering skills, is a desired graduate characteristic for employers. These conclusion are supported through a study of Northern Michigan University's MET bachelors degree graduates. A larger percentage of students with the CNC concentration found employment in their field, at higher starting salaries, than their counterparts who had a different concentration. It was also found that a high number of graduates with the CNC concentration utilized their CNC skills in their job function, likely improving job satisfaction.

Engineering technology bachelors degree's that are coupled with a significant element of CNC skills is a rarity in the upper Midwest, and likely nationwide. Engineering technology departments are encouraged to implement CNC based courses in their curricula.

REFERENCES

[1] Basken, Paul., Jan 30, 2009, "Engineering Schools Prove Slow to Change," The Chronicle of Higher Education.

[2] Fang, Ning., 2009, "A project-based active and cooperative learning approach to improving manufacturing engineering education," 284, *Proceedings of 2009 Annual American Association of Engineering Educators Conference*.

[3] Yousef, Eaglin., 2018, "Curriculum and Specializations Framework to Address Skills Required by Manufacturing Companies," 22343, *Proceedings of 2018 Annual American Association of Engineering Educators Conference.*

[4]https://data.bls.gov/projections/occupationProj, January 2019.

[5]https://www.bls.gov/oes/2017/may/oes514012.htmJ, January 2019.

[6] Rahemi, Elzawawy, Budhoo., 2018, "Advanced Manufacturing Engineering Technology Program: A Program that Prepares Graduates for Today's Manufacturing Industry," 21168, *Proceedings of 2018 Annual American Association of Engineering Educators Conference.*

[7](https://www.sba.gov/sites/default/files/advocacy/2018-Small-Business-Profiles-MI.pdf), January 2019.

[8] Martin, Polkinghorne, 2011, "Breaking Down Classroom Walls: Fostering Improved Communication and Relations between Engineers and Tradesmen through a Joint Semester Project", 62229, *Proceedings of the ASME 2011 International Mechanical Engineering Congress & Exposition IMECE2011.*

[9] Baytiyeh, Naja, 2011, "Challenges Facing Graduating Engineers in their Transition from College to Career", AC2011-1421, *Proceedings of the 2011 Annual American Association of Engineering Educators Conference.*

[10] Erez, M., 1981, "Fostering a career in Engineering". *Journal of Vocational Behavior,Vol. 18,pp. 115-120.*