Advancing the Manufacturing Engineering Technology Pathway: Innovating and Developing the Curriculum (Courses and Labs) from Associate to Bachelor's Level

Afi Anuar, Vukica Jovanovic, Nathan Luetke, Hamid Eisazadeh, Isaac Flory, IV, Mileta Tomović, Anthony W. Dean
Old Dominion University

Abstract

The southeastern region of Virginia, specifically Hampton Roads, has a diverse manufacturing landscape encompassing a range of enterprises, from small businesses to large corporations. This sector includes shipbuilding, construction machinery, aeronautics, and food processing. However, both the region and the broader state of Virginia are struggling with a skilled labor shortage that fails to meet the demands of these manufacturing enterprises. This paper aims to provide insights into the recently established Manufacturing Engineering Technology (MFET) program at Old Dominion University, located in Norfolk, Virginia. The MFET program features a comprehensive curriculum, encompassing the development of new courses and the establishment of a state-of-the-art smart manufacturing laboratory. This program has been initiated in collaboration with the Institute for Advanced Learning and Research and Patrick & Henry Community College in Martinsville, VA, and a grant funded by the U.S. Department of Veteran Affairs. The paper delves into the intricate process of creating the MFET curriculum, ensuring that it aligns with the requirements and needs of all partnering organizations, but more specifically industrial constituents who are going to hire manufacturing engineering technology graduates.

1. Introduction

Manufacturing has experienced a resurgence following a significant decline in employment numbers between 1997 and 2007. During this period, it transitioned from constituting 12% of statewide employment and over 13% of total wages in 1997 to 7.8% and 8.2%, respectively, in the Commonwealth of Virginia by 2007. This transformation took place concurrently with the shift in the economy from a manufacturing-based model to a service-oriented one [1]. However, if the manufacturing industry and associated occupations continue to decline, focus will need to shift to addressing the potential for an increasing skills gap across the commonwealth [1]. Areas that have achieved the highest degree of success in terms of manufacturing employment are Northern Virginia, the Capital Region and Hampton Roads. Consequently, the establishment of a manufacturing workforce program in southeastern Virginia would prove highly advantageous to the region. The MFET program complements and provides partnership to already existing workforce development programs, and Associate of Applied Sciences (AAS) programs that are offered by local community colleges.

Jobs of the future will not be the same as they were several decades ago, so undergraduate education is adapting for preparing engineering technology students for the future of work, which includes more training on human and technology integration, coupled with cloud computing, integration of artificial intelligence, new communication technologies, and cybersecurity related technology changes [2-4]. The future of manufacturing will see an exponential increase in the application of cobots in automation, smart sensing technology, additive manufacturing, and related metrology and quality assurance methods that are integrated within the manufacturing processes due to the ongoing rapid technological changes [5-8].

Numerous studies indicate that the future of manufacturing is bright, but they also indicate that the requirements on the workforce are changing and will continue to change at an accelerated rate [9], [10]. The level of educational and vocational preparation for manufacturing jobs has escalated with the introduction of automation, robotics, and highly specialized equipment that demand educational and vocational preparation in a way that has not been seen before. Future trends in advanced manufacturing point to an increasingly automated world that will continue to rely less on labor-intensive mechanical processes and more on sophisticated information-technology intensive processes. This trend will likely accelerate as advances in manufacturing are implemented. Over the next 10 years, advanced manufacturing will become progressively globally linked, as automation and digital supply-chain management become the norm across enterprise systems.

2. Market Demand

Old Dominion University (ODU) is located in an area that offers diverse manufacturing industries including small to large enterprises, shipbuilding and construction machinery, aeronautics equipment and aircraft parts, and food processing. The Hampton Roads area is home to over 250 manufacturing companies, ranging from small (several employees) to large companies (several thousand or tens of thousands of employees). The manufacturing industry in Hampton Roads employs over 60,000 people and has an impact on several times as many people who are involved with it in some manner. In addition to the traditional manufacturing industry, Hampton Roads is home to NASA, Jefferson Lab, and the U.S. Navy, each with significant needs related to manufacturing.

ODU has the unique opportunity to position itself as a flagship manufacturing engineering technology academic institution in Hampton Roads. The ODU Engineering Technology (ET) program and faculty can provide future MET students with advances on the Internet of Industrial Things (IoIT), cobotics, augmented reality, and additive manufacturing. The most prevalent manufacturing processes and enabling systems represented in Hampton Roads industries include welding, metal forming, casting, machining, injection molding, composites, robotics and automation, and digital twin, and smart manufacturing.

There were 236,600 people employed in the manufacturing industry in the Commonwealth of Virginia in 2021 [11]. Most of the people work in transportation equipment manufacturing (~44K, food manufacturing (~31K) and fabricated metal products (~17K) [12]. Short-term projections for the industry in Virginia indicate around 223,385 people were employed in manufacturing in 2020-2020 and manufacturing jobs are increasing [13]. Individuals that might enroll in this program would be [14] high school graduates, transfer students coming from community college, technicians, supervisors, or manufacturing personnel who want to move their career on the different level. Some students might also move to this major from other programs.

3. Design of New Program

ODU is launching a dedicated MFET program. Previously, the MET program had a concentration in manufacturing systems. The MFET program has been established in partnership with Institute for Advanced Learning and Research (IALR) a workforce development organization, and Patrick and Henry Community College (PHCC). The funding for the initial starting two years came from the externally funded project from U.S. Department of Veteran Affairs.

The curriculum being developed for the MFET program involves the creation of new courses and the establishment of a state-of-the-art smart manufacturing laboratory. Existing and newly hired faculty members will be involved in the development of these new courses. The smart manufacturing laboratory will be equipped with cutting-edge manufacturing equipment to offer students a realistic and hands-on manufacturing experience. The equipment encompasses metrology, assembly, processing, robotics, additive manufacturing, and programmable logic control equipment. This diverse range of equipment will enable the inclusion of practical, hands-on activities in the courses.

Developing a comprehensive four-year curriculum necessitates close collaboration among ODU, IALR, and PHCC. While all three organizations recognize the importance of the MFET program and the benefits of their partnership, they each have specific requirements that must be fulfilled. For instance, the university must adhere to ABET accreditation standards, while the workforce development organization is driven by industry-specific needs. Moreover, the community college aims to offer a two-year applied associate degree, while the university grants a four-year bachelor’s degree. The paper delves into the intricate process of developing the MFET curriculum to meet the requirements of all three partnering organizations. It will cover the range of courses offered, the collaboration efforts, and the utilization of the cutting-edge smart manufacturing laboratory. The ultimate goal is to ensure that the program successfully prepares students for rewarding careers in the field of manufacturing.

Currently, there are over 30 ABET-accredited MFET programs located in the US and internationally [15]. Langhoff and Shattuck (2022), Ahmad (2016), and Mohammed et al. (2010) detailed case studies at different institutions on developing electronics manufacturing technician and manufacturing engineering technology programs [16]-[18].

These programs were either developed based on completion of certificate at technical or community college or developed independently by a community college or university. The program provides a pathway for students from community college to continue their study to the MFET program at ODU. Mohammed (2013) wrote a paper on introducing manufacturing engineering to high school students with the Governors Scholars Program [19].

4. Method

This paper is a case study approach of developing a MFET program where a team of faculty from the ODU ET Department collaborated with members of the industrial advisory board (IAB), community college and a workforce development organization. In developing the curriculum, the role of IAB is to identify the subjects that are important in the manufacturing industry. ET, PHCC, and IALR created a course transfer and articulation of credits for the MFET program after the curriculum was approved by the both the MFET curriculum committee and the IAB. The team reviewed the course content offered at PHCC and IALR and compared them to ODU and ABET requirements. For students who completed their AAS degree from PHCC and wished to continue their studies, this team developed a pathway for students to enroll in Bachelor of Science (B.S.) degree at ODU.

For the articulation agreement to be attractive to potential students, the number of required credits for completion must be kept to a minimum. A thorough review of the courses required for the two-year applied associate degree at PHCC and the required courses and electives in the new four-year MFET curriculum at ODU was performed. A mapping of course objectives between the two programs was completed and commonality of content was identified between the 200-level applied courses at the community college and 400-level senior electives at ODU. Using this analysis, it was determined that for this articulation agreement only, students completing the two-year applied associate degree at PHCC would be given credit for two of the required senior electives in the four-year MFET curriculum (six credits). In addition to this, students are given credit three courses at the freshman level of the four-year MFET degree, (nine credits) reducing the total number of credits required for completion by 15. The current articulation agreement, pending approval, requires 141 credits: 66 credits at PHCC and 75 credits at ODU.

For students who prefer a traditional four-year college rather than a transfer program, the MFET is available to them to enroll at ODU starting from year one and requires 121 credits for completion.

5. Smart Manufacturing Laboratory

The Smart Manufacturing Laboratory (SML), in its initial stage was designed as a conventional CNC lab. It was supposed to have three CNC lathes, four CNC milling machines, one coordinate measurement machine (CMM) and eight CNC training panels (see Figure 1).

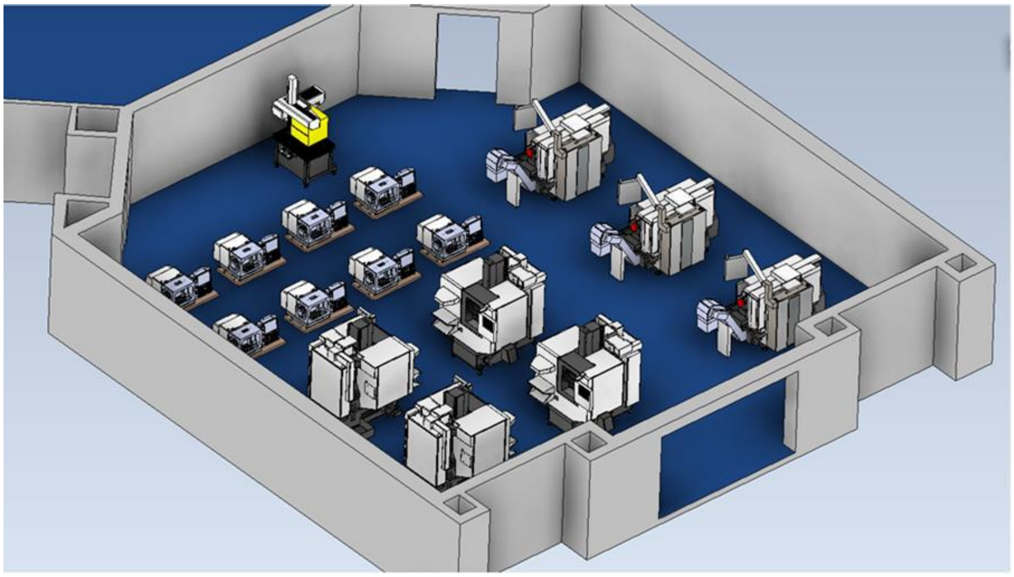

Fig. 1. First design iteration of smart manufacturing lab.

Owing to limitations associated with the facility's location, construction constraints linked to the building, and the expenses associated with necessary electrical, HVAC, and other updates required for this specialized laboratory, alongside industry-identified needs for the BS level manufacturing engineering technology workforce, the lab underwent a transformation to its present state as an advanced facility. It is now outfitted with state-of-the-art equipment including a coordinate measuring machine (CMM), vision measurement tools, robotics, a distribution line, and a sophisticated smart manufacturing system, as shown in Figure 2.

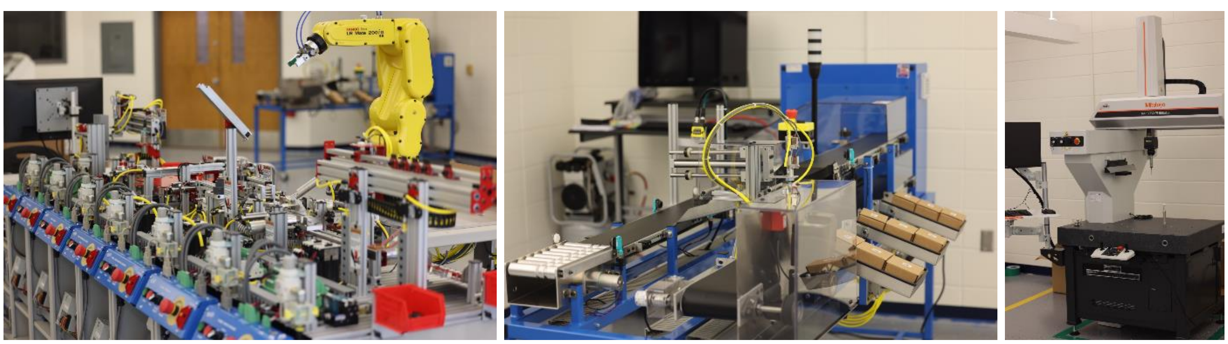

Fig. 2. Smart manufacturing lab.

6. Results and Discussion

Members of the IAB have identified several areas of studies. They were but not limited to manufacturing processes and standards, geometric dimensioning and tolerancing (GDT), welding technologies, additive manufacturing, statistical process control, lean engineering, automation and controls, advanced manufacturing processes, industrial robotics, mechatronics, computer numerical control in production, design for manufacturing, computer integrated manufacturing, industry 4.0, and 21st century workplace. Other areas include electrical labs, automation and controls, electrical power and machinery, cyber-physical systems, IoT, and smart devices.

Additional courses can be easily integrated such as occupational safety and health administration course.

ET programs already have laboratories for automation & controls, industrial robotics, welding, material science, thermofluids, hydraulics, design studios and additive manufacturing. The department will need to procure equipment for GDT, manufacturing processes and metrology. In addition to laboratories and equipment, two lecturer faculty lines is required to teach several MFET courses. This information is intended for any organizations planning in developing similar program. The SML is created specifically for the MFET program. SML is equipped with state-of-the-art equipment. This equipment provides students with practical and hands on learning experience. The automated assembly line is for students to learn mechatronics and the assembly process. Students also learn about automation and controls, robotics and Industry 4.0. The metrology section of the SML includes equipment such as CMM, vision measuring machine and height gages. Using these equipment students experience hands on practice on performing dimensional measurements. GDT learning kits enhances students experience in connecting dimensional measurements to fit, form and function. The automated distribution line is for students to learn programming logic control (PLC), maintenance, and automation and control.

In addition to in class learning and SML students have access to the state-of-the-art M-Lab at the Batten College of Engineering Technology and are taking manufacturing processes introductory courses at Darden College of Education and Professional Studies Industrial Technology program. ODU students have access to various organizations in Hampton Roads that are offering internships and co-op experiences to the students while they are in the MFET program. The Department of ET offers credit for multiple internships in their curriculum. The MFET curriculum for a 4-year study is listed in Table 2.

Table 2. Curriculum design of Manufacturing Engineering Technology degree.

Year	***Courses***	***Credit Hours***
FIRST YEAR	Engineering	8
	Basic Science, Mathematics and/or Statistics	14
	English and General Education	6
SECOND YEAR	Manufacturing Engineering Technology	6
	Engineering Technology	14
	Basic Science, Mathematics and/or Statistics	4
	English and General Education	9
THIRD YEAR	Manufacturing Engineering Technology	12
	Engineering Technology	6
	Basic Science, Mathematics and/or Statistics	3
	English and General Education	9
FOURTH YEAR	Manufacturing Engineering Technology	12
	Engineering Technology	9
	English and General Education	9

In the first year, students enroll in general engineering and basic courses. The second year is when students start taking MFET courses, in this case it's 6 credit hours. The MFET credit hours increases in third and fourth years to 12 and 12, respectively. In addition to MFET courses, students take a variety of engineering technology courses from the mechanical and electrical programs in the ET department.

The main challenge in creating a pathway from AS to BS degree is establishing a map that connects all courses and meeting the requirements at each institution (i.e., ABET). The purpose of connecting the courses is to maximize the number of transfer credits between institutions. An articulation agreement provides AS students to transfer into MFET program as juniors. Any non-transfer basic courses will be deferred to junior and senior years while technical or engineering courses taken at community college will transfer to the MFET program. As students enroll or transfer into the program in the next few years it is expected that the mapping will evolve leading to an improve pathway from AS to BS.

7. Conclusions

This paper presents the collaboration between a university, community college and workforce development organization to develop a pathway from associate to bachelor's degree for a Manufacturing Engineering Technology program. While the process was challenging, an articulation agreement allowed students from community college to transfer to a university to pursue a bachelor's degree. While articulation agreements are common between community colleges and universities, they are often marred with a high non-transferable credit hours. The Manufacturing Engineering Technology program is different such that students who completed their associate degree can enroll at the university with a transfer credit of nearly 60 hours which will be counted towards their bachelor's degree. A traditional 4-year study is also available to the students who wants to pursue a bachelor's degree. This program can be used as a template for other institutions who wish to develop similar program. The process of mapping and articulation evolve over time as the Manufacturing Engineering Technology program matures.

References

[1] Commonwealth of Virginia, "WIOA State Plan for the Commonwealth of Virginia FY-2018," Retrieved on September 11, 2021, from: https://www2.ed.gov/about/offices/list/osers/rsa/wioa/state-plans/va.pdf

[2] B. Geluvaraj, P. M. Satwik, and T. A. Ashok Kumar, "The future of cybersecurity: Major role of artificial intelligence, machine learning, and deep learning in cyberspace," in International Conference on Computer Networks and Communication Technologies: ICCNCT 2018, Springer Singapore, 2019, pp. 739-747.

[3] A. K. Tyagi, T. F. Fernandez, S. Mishra, and S. Kumari, "Intelligent automation systems at the core of industry 4.0," in International Conference on Intelligent Systems Design and Applications, Cham: Springer.

[4] I. Ahmed, G. Jeon, and F. Piccialli, "From artificial intelligence to explainable artificial intelligence in industry 4.0: a survey on what, how, and where," IEEE Transactions on Industrial Informatics, vol. 18, no. 8, pp. 5031-5042, 2022. International Publishing, December 2020, pp. 1-18.

[5] S. Phuyal, D. Bista, and R. Bista, "Challenges, opportunities and future directions of smart manufacturing: a state of art review," Sustainable Futures, vol. 2, p. 100023, 2020.

[6] S. Sahoo and C. Y. Lo, "Smart manufacturing powered by recent technological advancements: A review," Journal of Manufacturing Systems, vol. 64, pp. 236-250, 2022.

[7] J. Lee, P. C. Chua, L. Chen, P. H. N. Ng, Y. Kim, Q. Wu, et al., "Key enabling technologies for smart factory in automotive industry: status and applications," International Journal of Precision Engineering and Manufacturing, vol. 1, no. 1, pp. 94-105, 2023.
[8] J. Butt, "A strategic roadmap for the manufacturing industry to implement industry 4.0," Designs, vol. 4, no. 2, p. 11, 2020.
[9] M. Ghobakhloo, "The future of manufacturing industry: a strategic roadmap toward Industry 4.0," Journal of Manufacturing Technology Management, vol. 29, no. 6, pp. 910-936, 2018.
[10] M. Rüßmann et al., "Industry 4.0: The future of productivity and growth in manufacturing industries," Boston Consulting Group, vol. 9, no. 1, pp. 54-89, 2015.
[11] National Association of Manufacturers, "2022 Virginia Manufacturing Facts," Retrieved on December 2, 2023, from: https://nam.org/state-manufacturing-data/2022-virginia-manufacturing-facts
[12] U.S. Bureau of Labor Statistics, "Virginia: Nonfarm employment and labor force data, seasonally adjusted, Mid-Atlantic Information Office," Retrieved on September 14, 2021, from https://www.bls.gov/regions/mid-atlantic/data/xg-tables/ro3fx9535.htm
[13] U.S. Bureau of Labor Statistics, "17-3027 Mechanical Engineering Technologists and Technicians, Occupational Employment and Wages, May 2020," Retrieved on September 14, 2021, from: https://www.bls.gov/oes/current/oes173027.htm
[14] Virginia Employment Commission, "Forecasted Employment and Wages by State and Local Workforce Development Area 1st Quarter 2009 - 4th Quarter 2019," Retrieved on September 14, 2021, from https://virginiaworks.com/_docs/Publications/LMI-Publications/Forecasted-Employment-and-Wages/PDF/LWDA-Forecasted-EandW-4qrt.pdf
[15] ABET “Program Search” Retrieved on September 25, 2023, from: https://www.abet.org/accreditation/find-programs/
[16] N. Langhoff, J. Shattuck, and J. Le, "Development of an Electronics Manufacturing Technician Program for Community College Students," in 2022 ASEE Annual Conference & Exposition, August 2022.
[17] A. Ahmad, "Articulation of Certification for Manufacturing," in 2016 ASEE Annual Conference & Exposition, June 2016.
[18] J. Mohammed, "Introducing Manufacturing engineering with Kentucky Governors Scholar Program," in 2013 ASEE Annual Conference & Exposition, pp. 23-820, June 2013.
[19] J. Mohammed, R. Narang, and J. Albayyari, "Developing A New Manufacturing Engineering Technology Curriculum," in 2010 Annual Conference & Exposition, pp. 15-377, June 2010.

Biographies

AFI ANUAR is a lecturer with the Engineering Technology Department at Old Dominion University. He received his PhD and MS from ODU, and his current interests are in the fields of manufacturing and transportation, which include fundamentals and theories, traditional and smart applications, AI, and resiliency. He has nearly ten years of experience working in the automotive industry where he was involved in product launches, metrology and high-volume production.

VUKICA JOVANOVIĆ, chair of Engineering Technology Department at Old Dominion University, is a renowned scholar with a PhD in Mechanical Engineering Technology from Purdue University. Her expertise spans digital manufacturing, industrial engineering, mechatronics, and robotics. She champions engineering pathways and technical education, fostering inclusion in STEM fields. With over 150 publications and $6.5 million in grants, her impactful research is supported by various prestigious organizations including the National Science Foundation and the U.S. Department of Education.

NATHAN LUETKE received his BS in Mechanical Engineering Technology from Old Dominion University in 2000, and an MS in Mechanical Engineering in 2006. While pursuing his master’s degree, Nathan spent two years at Swales Aerospace followed by one year at Lockheed Martin contracting for NASA Langley Research Center in Hampton, VA. While there he performed radiation analyses and shield optimization on models of the International Space Station, potential lunar habitats, and vehicles for transport to Mars to increase radiation mitigation for the astronauts and equipment. Nathan joined ODU in 2005 and is a lecturer in the engineering technology department.

HAMID EISAZADEH joined Old Dominion University in fall 2018. Prior to ODU, he served as a faculty member at the County College of Morris for one year. Dr. Eisazadeh earned his PhD in Mechanical Engineering from Clarkson University in New York. His research endeavors primarily focus on material and manufacturing; i.e., investigating residual stress formation in dissimilar welds and additive manufacturing. By employing advanced techniques such as finite element modeling and neutron diffraction measurement, his work contributes significantly to the understanding and mitigation of weld residual stresses and their associated consequences.

ISAAC (IKE) FLORY IV, an associate professor at Old Dominion University, holds a PhD in Electrical Engineering from Virginia Tech. With extensive industry experience at Hubbell Incorporated, he's obtained 25 U.S. patents and contributed significantly to domestic lighting standards. At ODU, he's garnered accolades for teaching and led research programs exceeding $500,000, focusing on energy systems. His publications span technical and educational journals, and he instructs courses in diverse engineering disciplines.

MILETA TOMOVIĆ joined Old Dominion University in 2008. He is currently serving as School of Supply Chain, Logistics and Maritime Operations, and is full professor of Engineering Technology with dual appointment with Department of Mechanical and Aerospace Engineering. He received his BS degree in Mechanical Engineering from University of Belgrade, MS degree in Mechanical Engineering from MIT, and PhD in Mechanical Engineering from University of Michigan. He is currently serving as chair of the Engineering Technology Department, Old Dominion University. His research interests include design, manufacturing systems and processes, product lifecycle management, and system dynamics and controls.

ANTHONY W. DEAN is assistant dean for Maritime and Defense Initiatives and full professor of Engineering Technology at Old Dominion University, Norfolk, VA. His research has focuses mostly on additive manufacturing, control systems, and the reliability and maintainability of complex systems. He has been selected as both a NASA and an ONR Faculty Fellow. He received his PhD from the Department of Engineering Management and Systems Engineering, and a BS. in Nuclear Engineering Technology at ODU. Additionally, Dr. Dean received an MBA from the College of William and Mary. Prior to is academic career Dr. Dean was director of Operations and Business Development for Clark-Smith Associates, P.C., and served as an electrician in the US Navy aboard the USS South Carolina and the USS Enterprise.