Innovative Baccalaureate Degree Program in Advanced Manufacturing Sciences

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Abstract

A nationally unique B.S. degree program in Advanced Manufacturing Sciences (AMS) has been designed and implemented at MSU Denver under the auspices of a newly created Advanced Manufacturing Sciences Institute (AMSI).

The goal of the new AMS degree program is to educate the next generation of manufacturing professionals who will be in high-demand by regional and statewide manufacturing companies, as well as by manufacturers nationally and internationally. Exposing students to the production-grade, state-of-the-art manufacturing equipment and materials that are driving advanced manufacturing in the U.S. and around the world, in both the additive and subtractive manufacturing areas, lies at the heart of the program.

In addition to a focus on technical skills development, the new program emphasizes soft skills, such as critical thinking, problem solving, teamwork, leadership and communication, which represent skills that are in high demand by the industry partners of the program. In addition, cyber risk and manufacturing data protection issues are integrated into the curriculum in order to expose AMS degree students to system vulnerabilities on the manufacturing side.

In an exciting time of cloud computing, rapid developments in additive manufacturing, robotics and the Industrial Internet of Things, it is vital, with respect to U.S. manufacturing, that we produce graduates well prepared to fill the professional manufacturing jobs of the future.

The multidisciplinary nature of the degree program is highlighted in the paper, as are the program's core competencies and skill set development emphases. In addition, the various industry partnerships formed to-date under the AMSI umbrella, with a view to supporting the degree program in a sustainable fashion, are highlighted.

1. Introduction.

As has been noted by various industry analysts, including Deloitte and the Manufacturing Institute [1], more than 2 million manufacturing jobs are projected to go unfilled in the U.S. over the next decade. Only around 40% of a projected 3.5 million manufacturing jobs are predicted to be filled, due to the so-called skills gap, which is the difference between the number of positions available and the number of candidates having suitable skill sets for those positions. As also reported in another recent study by Deloitte and the Manufacturing Institute [2], although a significant majority of Americans (over 80% of survey respondents) believes U.S. manufacturing to be critical to economic prosperity, standard of living and national security, public perception of manufacturing is not aligned with reality, particularly as it relates to Industry 4.0 and the digital thread. Of particular concern in this regard is that one-third of the

survey respondents in the study indicated that they would not encourage their children to pursue a manufacturing career.

Consequently, the problem is two-fold: First, the public perception, or misperception, regarding advanced manufacturing impacts enrollment of students in manufacturing-related education programs. Second, traditional programs within educational institutions, for the most part, are not currently producing graduates with core competencies sought by manufacturers, which include programming and hands-on operation of state-of-the-art manufacturing equipment, technology/computing, mathematics and problem solving. For instance, many graduate engineers are not experienced in designing for additive manufacturing or applying the computer aided manufacturing (CAM) applications that are driving modern manufacturing. In addition, graduates of traditional programs may lack an understanding of the importance to employers of soft skills, such as critical thinking, problem solving and communication.

With the confluence of developments in robotics, machine programming, the Industrial Internet of Things, additive manufacturing and data analytics, advanced manufacturing is being driven by technological advances and rapid innovation. Consequently, educational institutions need to think creatively, and along multidisciplinary lines, if they are to produce graduates having in demand skill sets, with a view to keeping U.S. manufacturing competitive on a global basis.

Encouraging efforts along these lines have been reported. For instance, Chen and Salama [3] expanded a Manufacturing Technology curriculum to include additive manufacturing, while Frank [4] reported on curriculum development for an interdisciplinary Manufacturing Engineering program. Of particular interest regarding the work reported by Frank was the development of an interdisciplinary capstone design course for the curriculum, providing students the opportunity to design, manufacture and market a product. Furthermore, Rahemi et al. [5] reported the development of a new advanced manufacturing Concentration within a Mechanical Engineering Technology program, which also includes a senior manufacturing capstone project.

The authors believe, however, that fully integrated degree programs designed around the core competencies expected of manufacturing professionals should be developed, particularly at the baccalaureate level, in order to satisfy industry demand. Typically, manufacturing is treated as a Concentration within traditional mechanical engineering programs; however, the focus in these programs tends to be on design, as opposed to programming and hands-on operation of advanced manufacturing equipment. Design for additive manufacturing, as opposed to subtractive manufacturing, is typically not emphasized, nor is the use of CAM applications.

The purpose of the present paper is to overview the design and implementation of a baccalaureate degree program in advanced manufacturing. The program represents a multidisciplinary curriculum designed to produce graduates for manufacturing professional roles, as opposed to traditional engineering roles.

2. Multidisciplinary B.S. curriculum to address current and future talent needs.

With a view to addressing the current, and anticipated future skill set requirement, as identified by our collaborating industry partners, a new baccalaureate degree program in Advanced Manufacturing Sciences (AMS) has been designed and implemented at MSU Denver, based on a common core with

concentrations model. The courses comprising the core, taught by faculty from a number of participating departments, are designed to provide students in the AMS program with the core competencies presented in Figure 1 below.

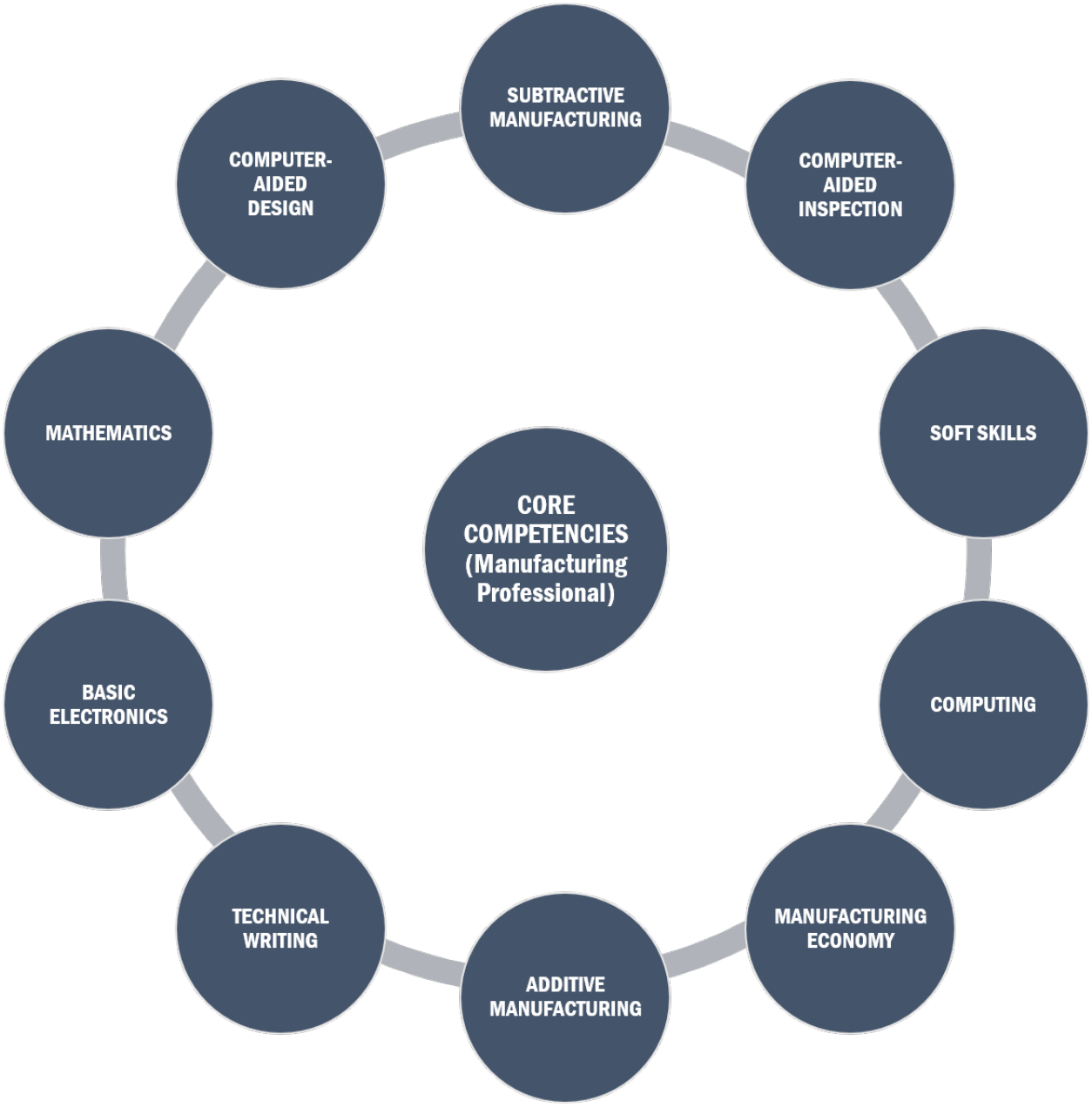

Figure 1: Core competencies identified for manufacturing professionals

All AMS degree students, regardless of their areas of concentration, pursue a set of required courses that align with the target core competencies illustrated in the above graphic.

Of particular note would be the Additive Manufacturing and Subtractive Manufacturing competencies, which involve an emphasis on hands-on exposure of students to state-of-the-art, production grade equipment, made possible through the establishment of industry partnerships (please see Section 3

below). In addition, CAD/CAM programming is emphasized in both of these competency areas. The program also has an emphasis on soft skills development, which is represented by the Soft Skills competency indication in the graphic. A course was created, in fact, in order to prepare all AMS degree students for careers in operational/manufacturing environments where leading, communicating and working as part of a diverse group is paramount to success. The "soft skills" course emphasizes the importance of leadership, communication and teamwork in an operational workplace, as well as the development of critical thinking, problem solving, reporting and professional relationship building skills. In addition, cyber risk and manufacturing data protection issues are integrated into the curriculum in the form of a newly created course aligned with the "Computing" core competency, in order to expose AMS degree students to system vulnerabilities on the manufacturing side.

The courses comprising the Core that are aligned with the various core competencies illustrated in Figure 1, are presented below in Figure 2.

Figure 2: Core courses aligned with core competency areas

In addition to satisfying the set of required Core courses, students elect to focus their studies, within the AMS degree program, in one of eight Concentration areas (currently offered), as illustrated in Figure 3 below. The Concentration areas correspond to traditional disciplines, allowing students to graduate with an understanding of a particular technical field, in addition to having the skill set required to excel in a manufacturing professional role.

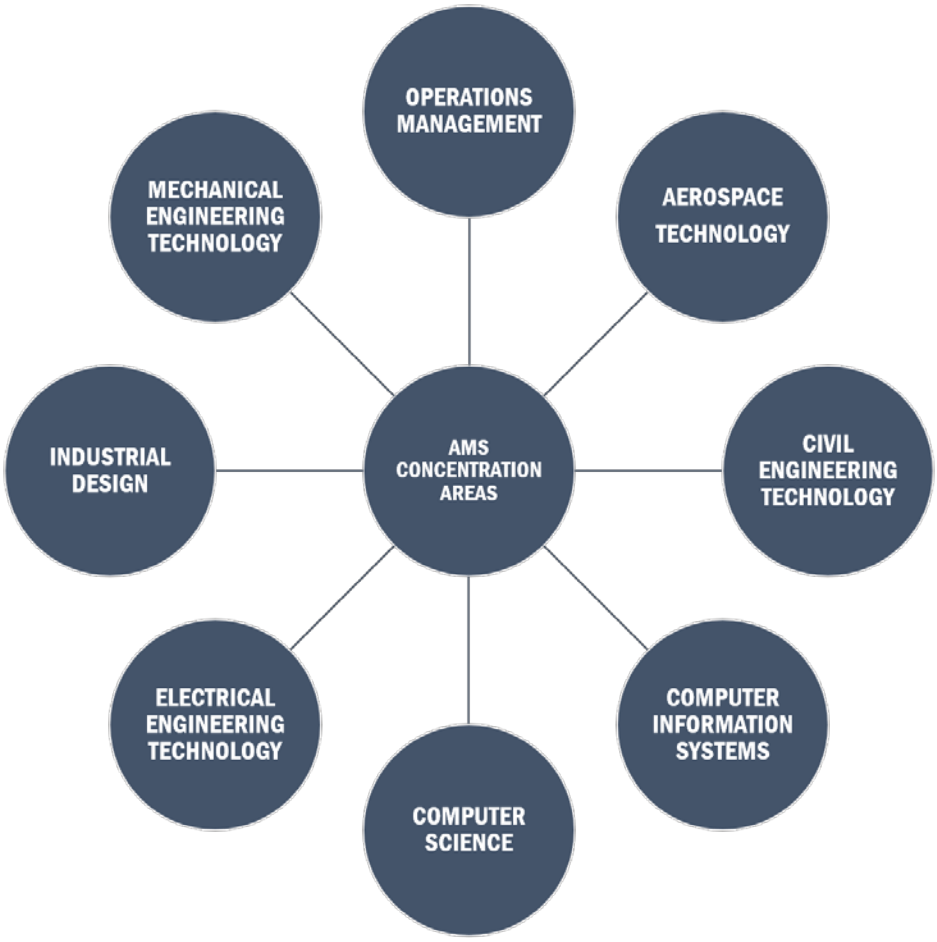

Figure 3: Concentration areas currently offered within the AMS curriculum

A future modification of the AMS curriculum under consideration is the creation of industry sector Concentrations, such as the aerospace sector, the automobile sector, the energy sector, the telecommunications sector and the bioengineering sector, for instance. The focus in such Concentrations would be on how advanced manufacturing techniques, materials and processes are applied to produce parts that are specific to the industry sectors in question.

3. Engagement of manufacturing companies seeking to develop talent pipelines.

The goal of the new AMS degree program is to educate the next generation of manufacturing professionals who will be in high-demand by regional and statewide manufacturing companies, as well as by manufacturers nationally and internationally. Exposing students to the production-grade, state-of-the-art manufacturing equipment and materials driving advanced manufacturing in the U.S. and around the world, in both the additive and subtractive manufacturing areas, lies at the heart of the program.

In order to inform and sustain the program, a number of collaborative partnerships have been created that ensure engagement of the manufacturing community. Partnerships have been formed with specific

companies and the following are examples of collaborative arrangements created and the benefits currently being realized:

Manufacturing Equipment Use and Loan Partnerships:

Partnerships have been formed with a number of equipment manufacturers and distributors, whereby AMS degree students, as well as students pursuing other majors, such as mechanical engineering, gain access to advanced, production-grade manufacturing equipment in a hands-on fashion. The equipment is provided on a loan basis, with the manufacturers retaining ownership of the equipment. A particularly attractive aspect of these arrangements is that the equipment manufacturers (and distributors) refresh the equipment on an ongoing basis, meaning that the program maintains its state-of-the-art status on an ongoing basis. Consequently, the program does not have long-term equipment maintenance concerns or issues relating to equipment (and technology) obsolescence over time. In addition, the program is not constrained, or limited, by the lack of a capital equipment budget. From an equipment manufacturer or distributor perspective, the program represents a branding opportunity and an equipment showcase opportunity. Moreover, having students gaining hands-on experience with their equipment represents a workforce development opportunity for the partner companies.

The vehicle by which students in the program gain access to the equipment associated with these types of industry partnerships (please see Figure 4 below) is a newly created course titled, “CNC Machining & Inspection”, which aligns with the program’s “Subtractive Manufacturing” core competency (please see Figure 1 above). Students become workforce-ready with an understanding of tool qualification and management, CNC machining (both vertical milling and Swiss-type lathe work), as well as automated inspection (employing coordinate measuring machines), in a production-grade environment.

Figure 4: Student access to state-of-the-art, production-grade equipment

Program investment by a large manufacturer, including an endowment:

A major investment of capital by a local space systems manufacturer led to the creation of a named laboratory housing a state-of-the-art, production-grade 3D printing machine. The fusion deposition modeling 3D printer in question represents the basis of the additive manufacturing program in effect at the partner company’s manufacturing facility.

Students in the program gain access to the equipment item associated with this particular industry partnership via a newly created course titled, “Additive Manufacturing Stratasys Certification

Preparation", which aligns with the program's "Additive Manufacturing" core competency (please see Figure 5 below). In addition to learning about additive manufacturing technologies currently employed in advanced manufacturing, such as fused deposition modeling, and working with state-of-the-art materials, such as production-grade thermoplastics, students have the opportunity to obtain an industry-recognized additive manufacturing certification, through an independently administered exam.

Figure 5: Additive Manufacturing lab & fall 2018 "Stratasys Certification Preparation" class photo

This particular partnership also has an endowment component, which will guarantee engagement in the program by the company on an ongoing, continuous basis.

The University's affiliate (adjunct) faculty program represents a direct form of engagement by our industry partners, with respect to course and curriculum evolution. The AMS degree program benefits significantly by having industry experts teaching the two core competency courses mentioned above, for example. These industry experts, working full time at our partner companies, lend their expertise to the AMS degree program by providing instruction and by being actively involved in course design and curriculum development. Since the AMS degree has an internship, or co-op, requirement, it is imperative to have active industry partnership involvement and industry experts being fully engaged with students in the program is an added benefit in that regard.

4. Initial review of the new degree program in terms of student and employer interest.

The AMS degree program was officially launched in the fall 2017 semester and enrollment in the program has risen steadily since that first semester, as indicated in the bar graph below in Figure 6. The growth trend is expected to continue, moving forward, based on ongoing promotional and marketing efforts focused on student recruitment.

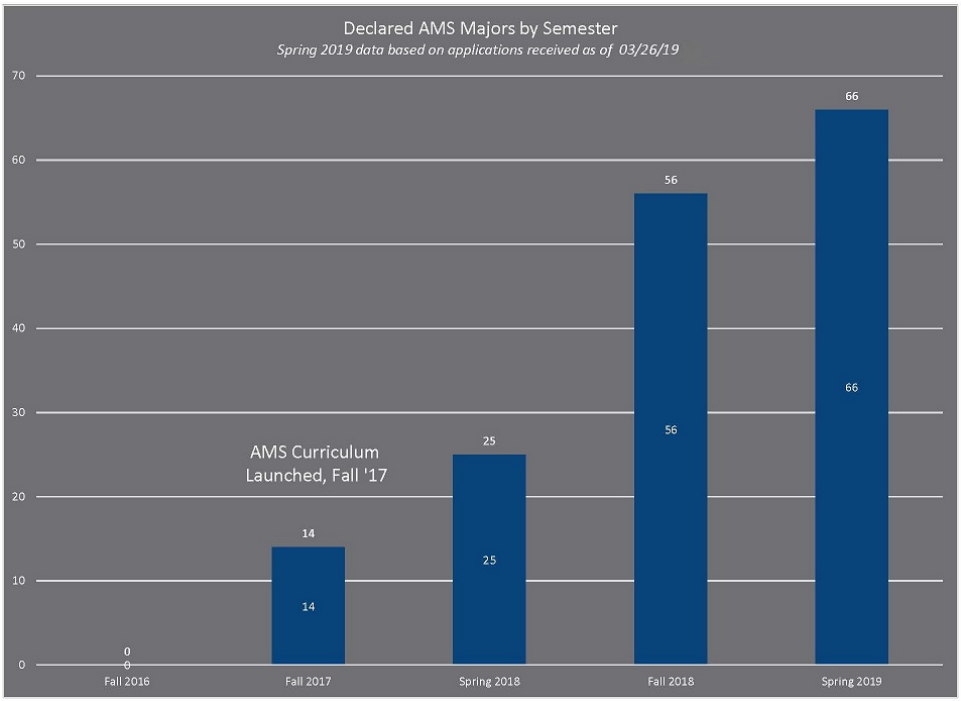

Figure 6: *Declared AMS majors by semester since launch of curriculum*

The first graduate of the AMS program, a transfer student, received his degree at the end of the fall 2018 semester. This student was employed as an intern with a local additive manufacturing company during his final two semesters and he received a full time employment offer upon receipt of his degree.

Currently, all eligible seniors are working as interns or co-ops and it is anticipated that these students will receive employment offers as they graduate from the program.

5. Summary

In summary, a unique multidisciplinary B.S. degree program has been developed and implemented that has advanced manufacturing as its focus, as opposed to being a Concentration, or an add on, associated with a traditional engineering curriculum. The program integrates technical competencies and soft skills and exposes students to state-of-the-art, production grade manufacturing equipment, materials and processes. The sustainability of the program is made possible by virtue of having engaged industry partners, in the form of course delivery by industry experts, ongoing involvement in curriculum development, internship and co-op program provision and ongoing advanced manufacturing equipment provision.

6. Acknowledgements.

The authors wish to acknowledge the valuable contributions made by faculty in the participating departments at MSU Denver (Engineering & Engineering Technology, Industrial Design, Aviation & Aerospace Science, Mathematical and Computer Sciences, Computer Information Systems and Business Management), with respect to the design of the AMS degree curriculum, and the ongoing support of the participating department chairs: Drs. Mingli He, Ted Shin (and predecessor Ken Phillips), Jeffrey Forrest, Abel Moreno, Lindsey Packer and Debbie Gilliard. In addition, the successful recruiting and advising efforts of Courtney Matsumoto, AMSI Program Administrator, are gratefully acknowledged.

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