October 25, 2012

To whom it may concern,

The Society of Manufacturing Engineers (SME) is the premier source for manufacturing knowledge, education and networking. Through its many programs, events, magazine, publications and online training division, Tooling U, SME connects manufacturing practitioners to each other, to the latest technologies and to the most up-to-date manufacturing processes. SME has members around the world and is supported by a network of chapters and technical communities. A 501(c)3 organization, SME is a leader in manufacturing workforce development issues, working with industry, academic and government partners to support the current and future skilled workforce.

SME considers itself a stakeholder in the NNMI, and is positioned to contribute to the success of the initiative. The society's members, leadership and staff have collaborated to address several of the questions contained in the NNMI Request for Information (Document Citation 77 FR 26509), and offer the following responses and recommendations for consideration:

1. What criteria should be used to select technology focus areas?

SME reviewed the AMP framework for prioritizing federal investment in advanced manufacturing technologies (see chart below) and believes it may be the best tool to select technology focus areas for the NMMI centers. This would promote consistency between technology selection and investment. In addition, SME would recommend adding criteria to the AMP framework that specifically account for the impact of the technology on employment and employability. While these could be implied under the heading "US Manufacturing Competitiveness" in the AMP framework, technologies that have strong impact on US employment or require significant supplemental federal investment to train the US workforce may need to be prioritized differently than a more simplistic prioritization based on "competitiveness".

Framework for Priorities for Federal investments in Advanced Manufacturing Technologies

US National Needs	Global Market Demand	US Manufacturing Competitiveness	Global Technology Readiness	Implication	Technology Required to Drive US Manufacturing Competitivenss	Role of US Government	Role of Industry	Role of University
High	High	High	High	Mature field. US strong global exporter.	Applied research & development to maintain leadership	Strategic demand requires capability.	Leads research & production investment	Conduct applied research
High	High	High	Low	US positioned for strong global leadership. Technology not available.	Basic to applied research	Strategic demand requires capability.	Defines roadmaps, develops technologies and establishes manufacturing capabilities & facilities.	Conduct basic research
High	High	Low	High	US lags. Net importer.	Big investment required to close gap.	Strategic demand drives establishing US manufacturing base.	Establish globally competitive manufacturing capabilities & facilities.	Breakthrough technology
High	High	Low	Low	New field. High export potential. No global Leader. New technology & infrastructure required.	Basic research	Strategic demand drives research & infrastructure build.	Partner with universities & national labs to conduct basic & applied R&D & establish required infrastructure.	Conduct basic research
High	Low	High	High	US specific need. Technology mature. Government roadmap drives infrastructure investment.	Infrastructure investment	Strategic demand requires capability & drives future infrastructure investment.	Establish infrastructure to meet national demand	Breakthrough technology
High	Low	High	Low	US specific demand. Government roadmap drives research and infrastructure investment.	Basic to applied research	Strategic demand sets requirements.	Establish infrastructure to meet national demand.	Conduct basic research
High	Low	Low	High	US needs; others produce. Low global demand. US vulnerable.	Big investment required to close gap.	Strategic demand drives infrastructure build & incentives.	Only establish capability if government funds.	Breakthrough technology
High	Low	Low	Low	US needs; no one produces; invention required.	Basic research	Strategic demand drives research	Establish infrastructure to demonsrate technology & meet national demand	Conduct basic research
Low	High	High	High	US leads; strong exporter. Industry drives research based on global demand.	Applied research	Incentivize exports	Industry leads research & invests in production.	Breakthrough technology
Low	High	High	Low	US leads; strong exporter. Industry consortium leads future roadmapping.	Basic to applied research	Incentivize exports	Industry defines roadmaps, develops technologies and establishes infrastructure.	Conduct industry funded basic & applied research
Low	High	Low	High	US not global leader. Commoditized market.	Big investment required to close gap.	Unless US vulnerable, no action required.	Only invest if breakthrough enables global competitiveness.	Breakthrough technology
Low	High	Low	Low	New field. High export potential. No global Leader. New technology & infrastructure required.	Basic Research	Incentivize exports	Drives research & infrastructure investment. Partners with universities to conduct basic research.	Conduct industry funded basic research
Low	Low	XXX	XXX	No demand. Don't do it.				

2. <u>What technology focus areas that meet these criteria would you be willing to co-invest in?</u>

The list of technologies produced by the AMP technology workstream represents areas where SME may be willing to co-invest based on the society's assessment of future market needs. Among these technologies, the priorities from SME's perspective would be:

- Advanced forming (including near-net-shape manufacturing) and joining/bonding technologies
- Advanced Material design and synthesis, including nano-materials, meta-materials, metals, coatings, and

ceramics. Composite and carbon-fiber based materials should be specifically included if they're not already implied to be included in the AMP list.
- Information technologies, including visualization and digital manufacturing. Product Lifecycle Management (PLM) should be specifically addressed and prioritized.
- Industrial Robotics
- Advanced sensing (including integrated RFID/sensing), measurement, and process control (also known as smart manufacturing or advanced automation)
- Smart Materials
- MEMS technology

3. What measures could demonstrate that Institute technology activities assist U.S. manufacturing?

SME would recommend several indicators or measures that could be used to demonstrate the assistance of Institute technology activities:
- Product lifecyle impact – enabling technologies that may extend the life of products (e.g. durable goods) or improve the environmental impact/sustainability of manufacturing operations.
- Productivity/concept to production acceleration – technologies from the institutes could have measurable impact on both productivity of manufacturing operations (information technologies/visualization) and/or the time it takes for a product to go from concept to production (Additive Manufacturing).
- Trade balance (import/export activity) in industries related to the institutes' technological foci.
- Intellectual property activity (creation and utilization).

4. What measures could assess the performance and impact of Institutes?

SME would consider the Institutes' performance and impact along the same criteria as other relevant federal assistance programs to the manufacturing industry, namely job creation/preservation and employment rate impact. Just as the NIST/MEP network expresses its value in terms of job creation or preservation, so to should the Institutes.
Also, achieving a self-sustaining business model within a reasonable time period will be an indicator of the Institutes' performance.

14. How should Institutes engage other manufacturing related programs and networks?

SME's suggestion would be to pursue commercialization of Institute technologies through business incubators, tech transfer organizations, and clients of the NIST/MEP network. This infrastructure is already in place and should be leveraged. In addition, Institutes should cultivate relationships with state manufacturing associations to connect Institutes to technology/industry clusters and/or existing stage 2 companies that could continue to develop and commercialize Institute technologies, or take them to market.

15. How should Institutes interact with state and local economic development authorities?

SME recommends Institutes cultivate relationships with state and local economic development authorities with a goal to educate the public about the economic impact of manufacturing. Institutes should also use organizations with national reach (like SME) to connect them with state and local economic development authorities in regions where there are technology clusters or industry clusters that could benefit from the work of the institutes.

16. What measures could assess Institute contributions to long term national security and competitiveness?

SME recommends that Institutes contribute to the maintenance of the Advanced Manufacturing Competency Model developed by the US Department of Labor. As Institutes pursue their work and make discoveries that impact US manufacturing, these learnings should be fed forward to the competency model to allow the industry to respond with transferable credentials that will maximize the competitiveness of the manufacturing workforce. Specific focus should be placed on how the work of the Institutes impacts the Industry-Sector Technical Competencies.

17. How could Institutes support advanced manufacturing workforce development at all educational levels?

18. How could Institutes ensure that advanced manufacturing workforce development activities address industry needs?

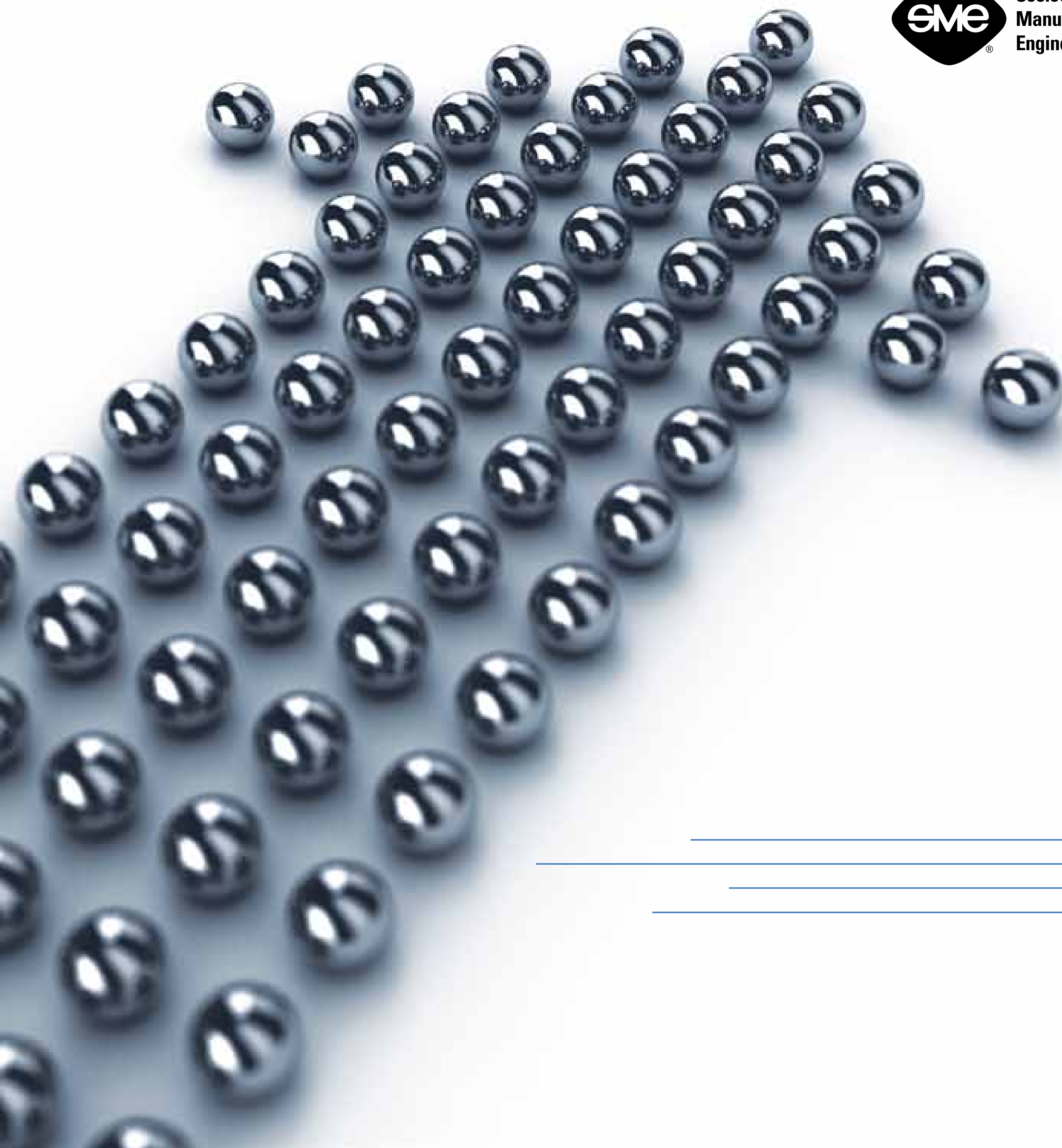
21. How might institutes integrate R&D activities and education to best prepare the current and future workforce?

SME recommends that Institutes incorporate the goals of the Workforce Imperative white paper (www.sme.org/workforceimperative) into their work to address workforce development issues, align with industry needs, and prepare the future workforce (questions 8, 9, and 10). Institutes could specifically help in focusing existing resources on programs that impact the workforce (Recommendation 6 in the white paper), and assist in attracting more students into manufacturing by making its work visible and available to educators to expose their students to it (Recommendation 1 in the white paper).

SME further recommends that findings from the institutes be used to update the Advanced Manufacturing Competency Model developed in collaboration with the US Department of Labor. The mode is referenced in the white paper and can be used to map training and certification of skills to competencies needed for skilled labor and engineering talent in the manufacturing workforce.

WORKFORCE IMPERATIVE: A MANUFACTURING EDUCATION STRATEGY

Society of Manufacturing Engineers



INTRODUCTION

Manufacturing education is in crisis. The evidence is striking and undeniable: Despite a consistently high United States unemployment rate for several years — ranging between 8% and 10% from February 2009 through March 2012[1] — as many as 600,000 manufacturing jobs have gone unfilled because of a shortage of skilled workers. The roots of this crisis started with a serious shortage of workers educated in Science, Technology, Engineering and Mathematics (STEM) fields, according to numerous reports.[2-13.]

A 2011 report authored by Deloitte and The Manufacturing Institute, "Boiling Point? The Skills Gap in U.S. Manufacturing"[3], notes that the biggest areas of workforce shortage "are those that impact operations the most and require the most training. From technicians to engineers, the talent crunch in these critical areas is taking its toll on manufacturers' ability to meet current operation objectives and achieve longer-term goals." Of manufacturers surveyed by Deloitte, 82% reported moderate to serious gaps in the availability of skilled production candidates. Respondents report, on median, that 5% of their jobs remain unfilled "simply because they can't find people with the right skills."

What's more, the report indicates that the shortage of manufacturing workers will likely get worse because of the advanced age of the current manufacturing workforce. "Fully 80% of respondents indicated that machinists, operators, craft workers, distributors and technician positions will be hardest hit by retirements in the upcoming years," Deloitte reports.

If the United States is to maintain its leadership in manufacturing — a sector that contributes greatly to the health of the overall economy, producing $1.7 trillion in goods, making up nearly 12% of the GDP and employing 9% of Americans[13] — the crisis in STEM and manufacturing education must be corrected.

Since it was founded in 1932, the Society of Manufacturing Engineers (SME) has advanced the education of manufacturing professionals across the spectrum, from technician and technologist to engineer, management and researcher. As part of SME's concern for manufacturing education in recent years, two SME groups — the SME Task Force on the Role of SME in Higher Education and members of SME's Manufacturing Education & Research Community — have examined the state of manufacturing education. This research included a series of events discussing manufacturing education that engaged hundreds of stakeholders from industry, government and academia. The input resulted in a report — "Curricula 2015: A Strategic Plan for Manufacturing Education"[14] — which served as the basis for the SME Center for Education to develop this white paper and its recommendations.

DISCUSSION

Manufacturing is a key component of a modern society, enabling people to build the goods and products they need to eat, live, entertain and protect themselves. However, the academic infrastructure needed to educate and train a workforce with the knowledge and skills necessary to support manufacturing is in need of serious repair.

In the United States, STEM investments and improvements are needed across the board, from K-20 to certification programs. Instead, a number of STEM programs are downsizing or have closed, including many hands-on technical programs. Meanwhile, students have shied away from STEM fields en masse. Against this backdrop of shrinking STEM interest and support, the manufacturing focus has not fared well. There are relatively small numbers of manufacturing students and graduates, outdated manufacturing curricula, resource shortages and a lack of emphasis on hiring, preparing and supporting manufacturing educators.

However, a recent surge of interest in rebuilding manufacturing competitiveness has resulted in a variety of as-yet uncoordinated efforts to boost manufacturing. Because of this growing interest, opportunities now exist to promote a comprehensive, systems-oriented solution to the many challenges facing manufacturing education.

This attention comes at a good time. As the United States emerges from the current economic downturn, the new jobs that do become available will require a higher level of advanced skill.[15] That means innovative new educational approaches will be critical in rebuilding the pipeline of manufacturing professionals.

SUMMARY OF RECOMMENDATIONS

To solve the manpower crisis in manufacturing before it gets worse, SME recommends that educators, industry, professional organizations and government work together to:

1. Attract more students into manufacturing by promoting the availability of creative, high-tech jobs and giving students a strong STEM foundation.

2. Articulate a standard core of manufacturing knowledge to guide the accreditation of manufacturing programs and certification of individuals.

3. Improve the consistency and quality of manufacturing curricula to better prepare students for manufacturing employment.

4. Integrate manufacturing topics into STEM education, so that more students are exposed to manufacturing concepts.

5. Develop faculty that can deliver a world-class manufacturing education in spite of a growing number of challenges.

6. Strategically deploy existing and new resources into STEM and manufacturing education programs.

Attract more students into manufacturing by promoting the availability of creative, high-tech jobs and giving students a strong STEM foundation.

How interested students are in manufacturing is strongly dependent not only on how they perceive the discipline but how well prepared they are to succeed in a manufacturing career.

Manufacturing must be portrayed as a vibrant industry that offers opportunities that are ample, creative, high-tech and rewarding. Many students tend to be altruistic in their choice of careers, so educational programs should make it clear to students that manufacturing offers the chance to improve the world.[16] For example, students should be educated about the role manufacturing plays in the green revolution that saves energy, increases health, saves lives and creates a new economy.

What's more, it is imperative that students are given a strong foundation in STEM disciplines, so they are exposed to concepts critical to manufacturing and prepared to succeed if they choose a career in manufacturing. Given the fast-growing number of minorities in the United States and their underrepresentation in manufacturing, an effort must also be made to engage more minorities in STEM programs so that this potential talent base can be tapped.

Once students express an interest in STEM and manufacturing, it is essential that faculty and others coach and mentor students to follow through to a career in manufacturing.

It is important to stress to students that there are multiple pathways, requiring different education levels, to a career in manufacturing. *Figure 1* shows several options. Associate and baccalaureate degrees can be immediately pursued after high school, and students who start in one program should be able to transfer to others. However, a significant portion of the available manufacturing jobs require educational equivalency up to an associate degree. In order to develop technicians, there must be more support for technical education, especially in high schools. Students must have options for manufacturing paths that are hands-on and technical or academic in nature — or, ideally, both.

Manufacturing Career Pathways

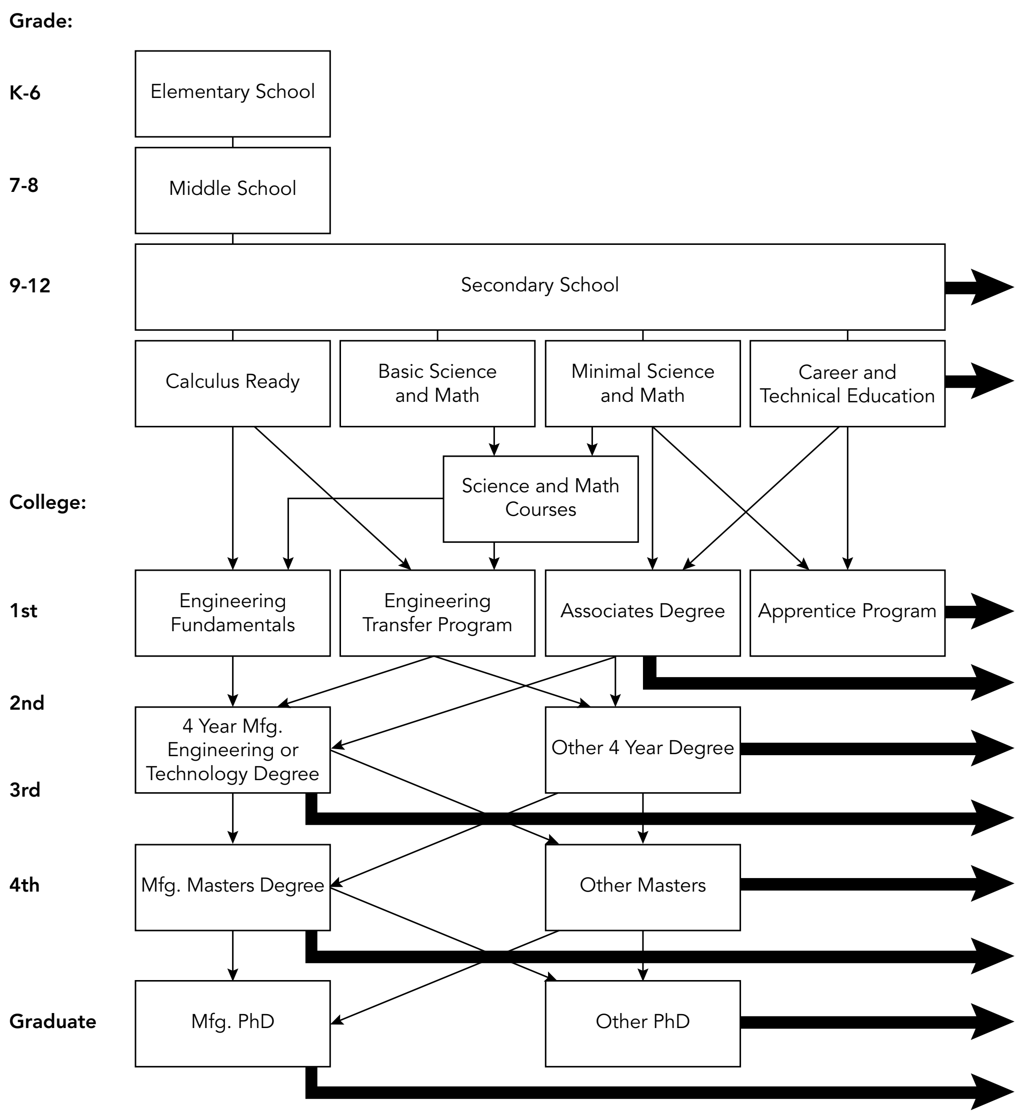


Figure 1. Institutional Pipeline for Manufacturing Knowledge.[14]

Articulate a standard core of manufacturing knowledge to guide the accreditation of manufacturing programs and certification of individuals.

What is manufacturing and what constitutes a manufacturing program?

Today, there is little agreement on the answer to that question. But if the crisis in manufacturing education is to be resolved, a better-defined manufacturing curriculum is needed to guide manufacturing education programs, with an eye toward accreditation. This will enhance the understanding and value of certifications and degrees that individuals receive from accredited programs.

The Department of Labor has taken a step toward defining the manufacturing skills workers need to be successful in 21st century manufacturing with its Advanced Manufacturing Competency Model [*Figure 2*]. The model was developed in 2006 in collaboration with the Employment and Training Administration and updated in 2010 with leading industry organizations. The National Association of Manufacturers, the National Council for Advanced Manufacturing and the Society for Manufacturing Engineers took the lead in collecting feedback from their members to ensure that the updated model includes the most current processes and practices.

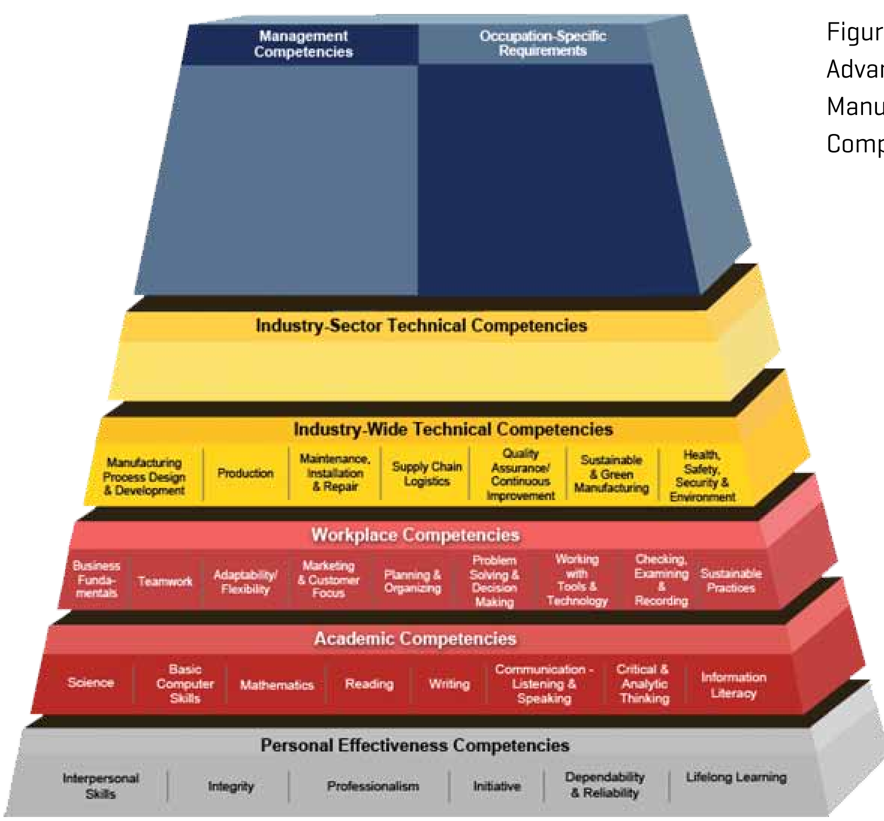


Figure 2. Advanced Manufacturing Competency Model.[18]

The shape of the Advanced Manufacturing Competency Model conveys the increasing level of specialization required in the manufacturing profession. The first two levels convey the foundational skills required for a career in advanced manufacturing, such as mathematics. The middle levels define the technical competencies required by the manufacturing industry, such as production and quality assurance. The top levels define the competencies required by specific occupations within advanced manufacturing.

This model serves as a framework for the National Association of Manufacturers-endorsed Manufacturing Skills Certification System [*Figure 3*], which is a system of stackable credentials from certification organizations applicable to all sectors in the manufacturing industry. These nationally portable, industry-recognized credentials validate the skills and competencies identified in the Advanced Manufacturing Competency Model.

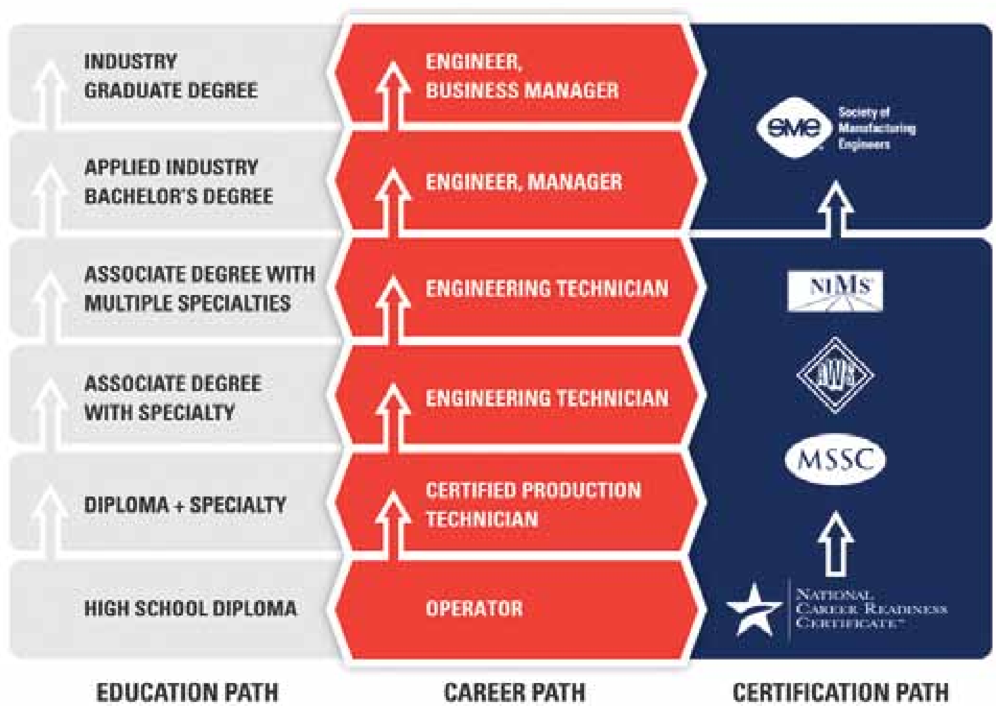


Figure 3. NAM-Endorsed Manufacturing Skills Certification System.

But there has been a missing link between the skills defined in the Advanced Manufacturing Competency Model and the Manufacturing Skills Certification System. A model was needed to define the academic content needed for manufacturing education programs, whether they confer degrees or technical credentials.

SME's Center for Education developed and adopted a model, which is included in the "Curricula 2015," to provide a solution to this problem. The Four Pillars of Manufacturing Knowledge [*Figure 4*] is meant to be a standard for recommending curriculum topics and establishing accreditation criteria for manufacturing programs of all kinds.

Content areas have been arrayed in a matrix under the ABET program criteria for accrediting manufacturing engineering and similarly named degree programs.[17] ABET is a nonprofit, non-governmental organization that accredits college and university programs in various science, engineering and technology disciplines. But whether a program aims for ABET accreditation or not, all manufacturing programs would benefit from using this governed body of manufacturing knowledge.

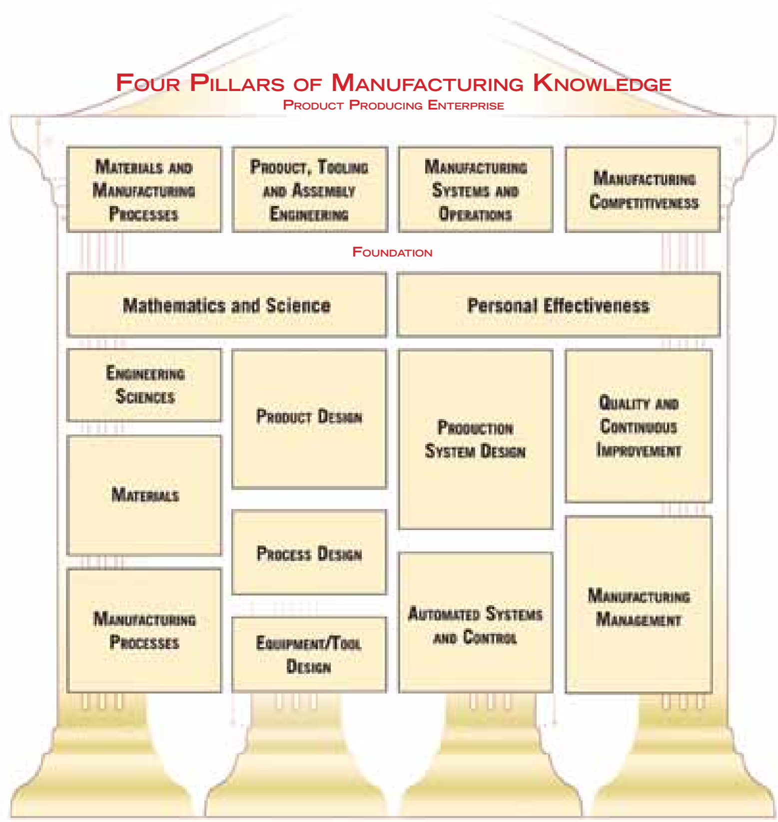


Figure 4.
Four Pillars of Manufacturing Knowledge.[14]

Together, these three models (*Figure 5*) demonstrate an integrated solution to the question of what manufacturing is and what content needs to be taught in a competent manufacturing program so that individuals can be certified. They also set important standards for accreditation of educational programs. Certifications and degrees that come from accredited programs are necessary for industry to verify and trust the level of skills and knowledge that certain individuals bring to the workforce.

Two-year community colleges and technical colleges, which educate technicians to run manufacturing operations, must be encouraged to seek accreditation. Schools should be identified that could become accredited and aligned with resources and support to become accredited and incorporate recognized certifications. Data must also be gathered and used on the need for manufacturing programs to become accredited and the needs of programs seeking accreditation.

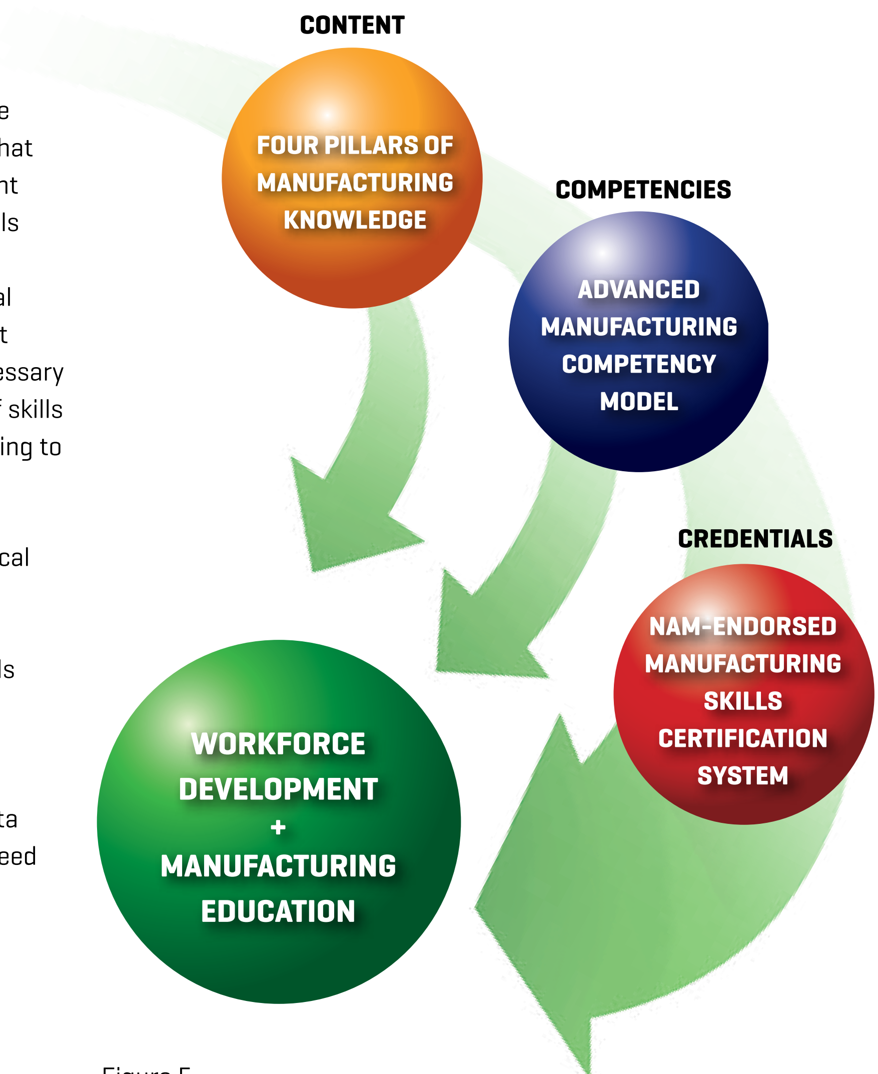


Figure 5.
An integrated perspective.

Improve the consistency and quality of manufacturing curricula to better prepare students for manufacturing employment.

Manufacturing curricula vary greatly from school to school and program to program. While some flexibility is necessary, everyone educated in manufacturing should have a basic core of knowledge.

SME recommends that educators, industry, professional organizations and government work together to:

- Use the Four Pillars of Manufacturing Knowledge and the Advanced Manufacturing Competency models as a foundation to build manufacturing curricula.
- Keep curricula current by monitoring trends in education and industry needs.
- Use curriculum and instructional resources shared through the National Center for Manufacturing Education,[19] a national clearinghouse of resources for educators and industry professionals.

Integrate manufacturing topics into STEM education, so that more students are exposed to manufacturing concepts.

It is crucial that manufacturing topics be integrated into STEM education programs more broadly. This will expose more students to manufacturing concepts, and it will also give graduates of STEM programs more well-rounded knowledge about how products are made, from design to production.

Many of those who currently enter the manufacturing profession do so after obtaining their education in other related fields. So while they may enter manufacturing with strengths in some subject areas of the Manufacturing Engineering Body of Knowledge, important knowledge and skills are typically acquired on the job. For years, industry has been citing the need for graduates to have a higher level of manufacturing knowledge prior to entering the workforce.

Recent surveys of early-career mechanical engineers and their supervisors find agreement that their curricula and preparation were weak in practical experience of how things are made.[20] To have truly integrated product and process design and manufacturing, all professionals who take part in that process need some common understanding of manufacturing.

SME recommends that educators, industry, professional organizations and government work together to:

- Integrate topics from the Four Pillars of Manufacturing Knowledge model into all STEM program areas.
- Bestow supplemental credentials, such as manufacturing minors or recognized certifications from the Skills Certification System, in STEM fields to align skills with industry needs.
- Create programs and communications linking STEM leaders and educators with those directly in manufacturing.
- Encourage faculty to submit ideas and practices on teaching manufacturing in nonmanufacturing-named programs to the National Center for Manufacturing Education for collection, evaluation and dissemination.

Develop faculty that can deliver a world-class manufacturing education in spite of a growing number of challenges.

K-12 educators and college faculty play a key role in inspiring interest in manufacturing careers, but they face many challenges in delivering a world-class manufacturing education. Those challenges include a lack of agreement on what constitutes a core manufacturing curriculum, a shortage of STEM and manufacturing literacy among students and educators, changes in education delivery and a lack of resources.

New initiatives are arising to address many of these issues.

On the STEM and manufacturing literacy front, the University of St. Thomas is introducing an engineering education minor and graduate certificate for K-12 teachers.[21] A similar program is under way at the University of Dayton for engineering technology.[22]

Meanwhile, technology is quickly transforming how faculty teach. The Internet provides a new path to learning and knowledge outside the boundaries of traditional institutions. Advancements now allow teaching and learning through online, digital-based and 3-D learning environments. Often, this digital education is free or low cost and offers ready access to a wealth of personalized content, as well as expertise in the form of networks of people. The National Academy of Engineering has identified "advancing personalized learning" as one of the grand challenges for engineering.[23]

Online enrollments are now growing faster than overall higher education enrollments, and 31 percent of all higher education students now take at least one course online.[24] Faculties have been exploring how traditional on-campus manufacturing courses and laboratories can be enhanced by online content. For example, courses offered by Tooling U have been assigned as homework to enhance learning and preparation for more efficient use of student time in manufacturing laboratories.[25]

To develop faculty that can deliver an excellent manufacturing education, educators must:

- Keep up to date on using new technologies.
- Work with industry to understand current technical needs and update curriculum.
- Collaborate with industry, professional organizations and government on projects such as design-and-build competitions and mentorships of both students and faculty.
- Research, publish and participate in manufacturing journals and conferences.
- Share best teaching practices, especially when it comes to alternative teaching methods, through appropriate continuing education programs for instructors at all levels. This includes in-service days and conferences, among other examples.

Strategically deploy existing and new resources into STEM and manufacturing education programs.

Manufacturing education is an essential priority and should be funded accordingly.

All sources of possible funding should be sought to support manufacturing education, and investments need to be strategic and effective, with measurable results. SME recommends that investments be guided by the Four Pillars of Manufacturing Knowledge, the Advanced Manufacturing Competency and the Skills Certification System models.

Many educational programs and initiatives that demonstrate the excitement and rewards of manufacturing are now under way for young students. Among the efforts: National Engineers Week activities,[26] "Dream it. Do It." campaigns,[27] SkillsUSA,[28] FIRST competitions[29] and the National Robotics Challenge.[30]

The SME Education Foundation (SME-EF)[31] is also involved in launching, developing and supporting a number of efforts. Among them:

- Computer-integrated manufacturing (CIM) courses, in conjunction with the Project Lead The Way®[32] curriculum.
- CareerME.org, a Web site designed by the National Center for Manufacturing Education.[19]
- ManufacturingIsCool.com, an award-winning, interactive Web site that engages students in basic engineering and science principles and provides resources for teachers.
- The Partnership Response in Manufacturing Education (PRIME) program, which provides a community-based approach to manufacturing education.
- The Edge Factor Show,[33] an exciting program designed to change the image of manufacturing by giving a fun inside look at advanced manufacturing technology.

All of these excellent programs and initiatives need continuing support and engagement by educators, industry, professional organizations and government.

A CALL TO ACTION

The crisis facing manufacturing education is a serious threat not just to manufacturers, but, ultimately, to the economy and security of the United States.

So while the strategic, corrective recommendations made in this white paper are extensive, they are urgent and necessary.

It is critical to improve STEM education and to dedicate a portion of that education to an agreed-upon core of manufacturing knowledge. This will help attract more students into STEM fields, including manufacturing. It is also essential that programs and curricula supporting STEM and manufacturing receive the investments and updates they need and that a qualified stable of educators is groomed for the future.

What's more, educators, industry, professional organizations and government must support nationally portable, industry-recognized accreditation of manufacturing programs and certifications for manufacturing professionals.

No one group can accomplish all of these actions. Collaboration is needed to set priorities and execute these objectives. The Four Pillars of Manufacturing Knowledge, the Advanced Manufacturing Competency and the NAM-Endorsed Manufacturing Skills Certification System models provide the framework on which to collaborate and build strong manufacturing education programs.

The commitment of SME, together with other like-minded individuals and groups, can increase the resources and support for these objectives and ensure that our nation is churning out qualified students and workers who can ensure that U.S. manufacturing remains strong.

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32. Project Lead The Way®, www.PLTW.org.

33. Edge Factor Show, www.edgefactor.com.

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