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Perceptions of the Advanced Manufacturing Competency Model (AMCM) for Curriculum Development

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Abstract

The Advanced Manufacturing Competency Model (AMCM) model emphasizes building of competencies at all levels ranging from the shop floor production worker to manufacturing engineers. It consists of different levels of competencies organized hierarchically. The levels are personal effectiveness, academic, workplace, industry-wide technical, industry-sector technical, management and organization-specific competencies.

This paper discusses survey research on the perceptions of manufacturing students, faculty, and industry advisory board members regarding the AMCM. The research evaluated the manufacturing program based on perceptions of the AMCM competencies and the curricular coverage required for entry-level manufacturing professionals. Specifically, the survey sought to answer the following research questions:

- What competencies of the AMCM are the most important for entry-level manufacturing professionals?
- What competencies of the AMCM are most frequently covered in the manufacturing program?
- Is the manufacturing knowledge specified by the AMCM congruent with what is being taught and what is important for entry-level manufacturing professionals?

Overall, the Advanced Manufacturing Competency Model was perceived compatible with the important competencies taught in the manufacturing program for an entry-level manufacturing professional. However, for most competencies, respondents perceived the extent of curriculum coverage to be less than the importance of the competency. Areas for consideration included an increased emphasis on professionalism, responsible behaviors, thinking skills, reading, oral, and written communication. In addition, respondents indicated the program should consider increased attention to the competencies of planning, organizational skills, adaptability, and practices for a safe work environment.

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Introduction

In 2006, the U.S. Department of Labor's (DOL) Employment and Training Administration (ETA) developed and released the Advanced Manufacturing Competency Model (AMCM) to provide a framework of the skillsets necessary for success in manufacturing jobs [1]. Since its release, the model has been considered a resource and guideline for manufacturing industries and educational institutes across the country. Considering that the requirements of skillsets are continually advancing in manufacturing, the DOL collaborated with the leading industry organizations to update the model in 2010. The National Association of Manufacturers (NAMS), the National Council for Advanced Manufacturing (NCAM) and the Society for Manufacturing Engineers (SME) took the lead in collecting feedback from their members to ensure that the updated model included the most current processes and practices. The model emphasized competencies at levels ranging from the shop floor production worker to manufacturing engineers. The AMCM includes seven different levels of competencies organized hierarchically. The levels are personal effectiveness, academic, workplace, industry-wide technical, industry-sector technical, management and organization-specific competencies. Figure 1 shows the updated AMCM as released by DOL in 2010 [2].

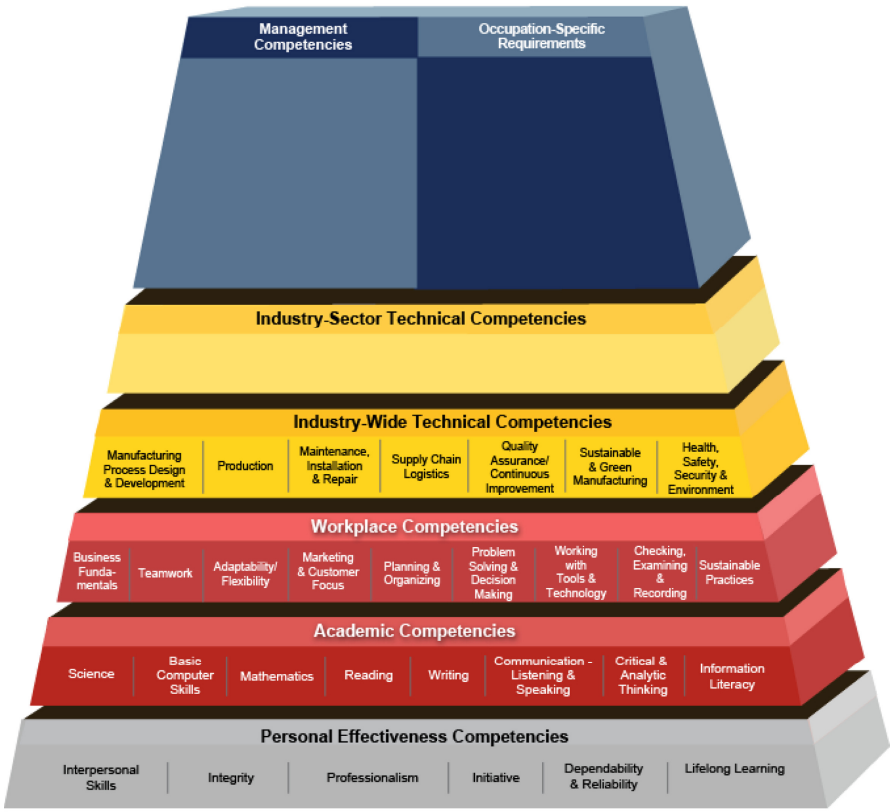

Figure 1: The updated Advanced Manufacturing Competency Model proposed by DOL [2].

One of the main goals of the Advanced Manufacturing Competency Model was to provide a framework for creating a robust pipeline of workers to address the growing needs of a skilled

manufacturing workforce. The report titled "Using Competency Models to Drive Competitiveness and Combat the Manufacturing Skills Gap" published by the SME, summarized the results of a survey on the skills gap and current training. It defined the difference between competency and competency models, explained the different competency models, and explored best practices [3]. According to the report, American manufacturers are having increasing difficulty finding skilled workers to fill good paying jobs. In 2013, an SME and Brandon Hall survey [4] stated "9 out of 10 manufacturers are having difficulty finding skilled workers; 64% of manufacturers say productivity losses are a result of a skills gap; 56% report the gap in skilled labor has impacted their company's ability to grow; and 78% cited a lack of qualified candidates as one of the top two factors that impacted their ability to hire a skilled workforce". Consequently, the US manufacturing industries began to view the AMCM more seriously and manufacturing associations in many states published papers calling for urgent action. The manufacturing associations also urged universities and community colleges to consider aligning their manufacturing education with the model.

Literature Review

According to the Manufacturing Institute [5], advanced manufacturing is critical to economic security since it pays wages higher on average than other industries, creates the highest number of jobs, both direct and indirect, and contributes to more than 50 percent of total US exports. It is important to develop a future workforce that could meet the increasing demand of manufacturing jobs. Different manufacturing organizations and state manufacturing associations have published white papers that provide guidelines and recommendations to meet the increasing challenge of developing a manufacturing workforce with the desired skillsets and competencies.

The AMCM and SME four pillars model are two models recommended as frameworks for academic institutions. The manufacturing associations and advocates of manufacturing urge that a competency-based education should be developed to ensure that schools teach the latest skills required by industry. Rietzke [6] discussed the importance of the AMCM in preparing the workforce with necessary skillsets and knowledge. Rietzke also urged educators and training providers to develop their curriculum based on the model. He suggested those skillsets be taught at the college level to enable students to find good jobs with advancing career pathways.

Lehigh Valley Workforce Investment Board, Inc. [7] in partnership with the Pennsylvania Department of Education Bureau of Postsecondary and Adult Education published a report urging the necessity of collaboration among the educational institutes and the manufacturing industries in the region to develop the next generation manufacturing workforce with skillsets suggested in the AMCM. The report also discussed the manufacturing career pathways based on the NAM-endorsed Manufacturing Skills Certification System, analyzed the gap in the skillsets necessary for those career paths, and suggested possible actions for educational institutions and industries.

Jackson [8] published a white paper investigating how the state of Massachusetts viewed the manufacturing sector as leverage for statewide economic planning and how manufacturing industries should align with the AMCM. The white paper provided educators and state leadership with guidelines on how secondary and postsecondary institutions could collaborate with the manufacturing industry to develop curriculums that would create the future manufacturing workforce.

The San Diego Workshop Partnership [9] conducted a research study documenting the growing opportunities in the advanced manufacturing sector by analyzing job postings, employer survey responses, employment statistics, and focus groups of educational and training providers and employers. The study provided a detailed analysis of the job growth, skills gaps, and need for necessary training in advanced manufacturing. The research also identified specific actions needed by employers and educators, and provided guidelines based on the AMCM for San Diego manufacturing industries. The Partnership recommended the AMCM to minimize the gaps in skill-sets for manufacturing professionals and the potential workforce.

In a report to the Northwest Indiana Fund, the Taimerica Management Company [10] identified the competencies and skillsets required for the three largest employment clusters of Northwest Indiana including advanced manufacturing, transportation and logistics, and insurance companies. In compiling the competencies, they used the AMCM as a foundation for their proposed model. The report found that manufacturers are experiencing difficulty finding and hiring workers with adequate skills and competencies at all levels. Therefore, the manufacturing programs in Indiana needed to address those gaps in skillsets among the new graduates and train them with regard to the AMCM model.

In addition to the white papers on advanced manufacturing, there have been several research studies on the requirements of advanced manufacturing competencies among the potential workforces. Darbanhosseiniamirkhiz and Ismail [11] investigated the influential factors that led to the adoption of advanced manufacturing technology (AMT) model by SME. They also identified the challenges that medium and small manufacturing companies overcome to accomplish the goals of advanced manufacturing technology utilization. They analyzed previous studies on advanced manufacturing technologies and proposed a model of determining factors for the adoption of AMT.

Barber and Tietje [12] investigated the competency requirements for the technology managers in manufacturing, assembly, and materials processing functions. They identified 14 knowledge, skill, and value-based competencies and three higher-order factors as essential components for manufacturing management professionals. The findings from the study indicated that in order to be effective, manufacturing managers must possess a unique balance of interpersonal and leadership skills that are commonly associated with managers in general, as well as a significant depth of technical knowledge and skills about engineering, design, manufacturing, and operations.

Lowden, Hall, Elliot, and Lewin [13] conducted research to assess the perceptions of employers and higher education institutions with regard to graduates' employable skills and knowledge. They discovered that all organizations expected graduates to exhibit technical and discipline-related competencies based on their acquired degrees. In addition, employers also expected graduates to have a wide range of skills such as teamwork, leadership, communication, critical thinking, and problem solving abilities. The researchers recommended development of programs to promote and recognize experiential and work-related learning.

Several educators and researchers have assessed their curriculum against the SME four pillars model and suggested curriculum alignment with the model. According to Mott, Jack, Raju, and Stratton [14], manufacturing program developers should incorporate the concept of the four pillars in designing curricula and provide a means of communicating the nature of academic preparation and performance to students, employers, and other entities. Nutter and Jack [15] conducted a survey among industry practitioners, managers, company owners, and educators on the applicability of the SME four pillars in manufacturing curriculum. The participants were asked to indicate how important each topic was for graduates of these programs. Based on the survey responses, the study recommended that manufacturing programs prepare their graduates based on the demands of industry and align their curriculum with SME four pillars to fill the gaps in the skillsets. Doggett and Jahan [16] conducted a survey among the students, faculty, and industry advisory board members of an advanced manufacturing program to investigate the knowledge of SME four pillars and to identify the skillsets required for an entry-level technology manager. The study concluded that the professional or non-technical skills, such as leadership, interpersonal skills, and communication skills are as important as technical skills for an entry-level technical manager.

There have been very few studies on assessing or revising the curriculum on the light of advanced manufacturing model. Kirkwood Community College [17] made extensive use of the AMCM in developing the curriculum for associate degree programs of study in advanced manufacturing and robotics technologies. They worked with their industry advisory board to address the skills gap and used the AMCM to engage faculty and staff in developing the curriculum. They also urged for the collaboration among the colleges and universities across the state to develop a common core curriculum focusing on the AMCM.

It can be seen from the literature review that although there have been many white papers published by manufacturing associations on the necessity of the advanced manufacturing model, very few studies have assessed curriculum against the model. It is; therefore, important that universities and community colleges assess their manufacturing programs against the AMCM and seek alignment with it to reduce potential gaps in the skillsets necessary for entry-level manufacturing professionals. This study evaluated a current manufacturing program against the AMCM based on the perceptions of students, faculty and industry advisory board members of the program. The manufacturing programs were surveyed regarding the knowledge required for entry level manufacturing professionals. Specifically, the survey sought to answer the following research questions:

- What competencies of the AMCM are the most important for entry-level manufacturing professionals?
- What competencies of the AMCM are most frequently covered in the manufacturing program?
- Is the manufacturing knowledge specified by the AMCM congruent with what is being taught and what is important for entry-level manufacturing professionals?

The program studied was a manufacturing engineering technology program. Students of the program take both technical and managerial courses. Completion of general education science and trigonometry is required. Graduates of the program obtain a variety of positions in the manufacturing industry including engineering, production management, quality, and maintenance jobs.

Research Method

A survey, developed using the web-based software Qualtrics, was sent to approximately 80 students and alumni of the advanced manufacturing program. Forty-four initially responded (55%) with 14 completing the entire survey (17%). The questions were based upon the AMCM model's first four levels of competencies (1) personal effectiveness, (2) academic, (3) workplace, and (4) industry-Wide Technical– Entry-Level. For each level, respondents were asked to rate each competency on a scale from 1 to 5, with 5 representing the *most important competency* and 1 the least important. In addition, respondents were asked to rate each competency with 5 representing the *most frequently covered* in their manufacturing program and 1 representing the least covered. For each competency level or tier (four levels), the following two questions were asked (eight questions total):

- Rate the following as most important (5) to least important (1) for an entry-level manufacturing professional.
- Rate the following from most covered (5) to least covered (1) for your manufacturing program.

An additional question, using a Likert scale (with 5 being strongly agree and 1 being strongly disagree), asked respondents to indicate their perception of the following statement:

- Is the Advanced Manufacturing Competency Model compatible with what is being taught in your manufacturing program and the competencies that are important for an entry-level manufacturing professional?

Results

The findings of the survey follow. For the personal effectiveness competencies, respondents rated initiative and dependability/ reliability highest in importance with integrity having the most coverage. Lifelong learning was perceived lowest in importance and professionalism least covered. See Table 1 and Figure 2.

Table 1: Personal Effectiveness Competencies Responses

	Perceived Importance		Extent Covered	
	Mean	Std Dev	Mean	Std Dev
Interpersonal Skills: Demonstrating the ability to work effectively with others.	3.5	1.26	3.08	1.04
Integrity: Displaying accepted social and work behaviors.	3.75	1.24	3.31	1.38
Professionalism: Maintaining a socially acceptable demeanor.	3.69	1.2	2.77	1.01
Initiative: Demonstrating a willingness to work.	3.88	1.41	3.23	1.54
Dependability & Reliability: Displaying responsible behaviors at work.	3.88	1.45	2.92	1.32
Lifelong Learning: Displaying a willingness to learn and apply new knowledge and skills.	3.38	1.15	3.08	1.19

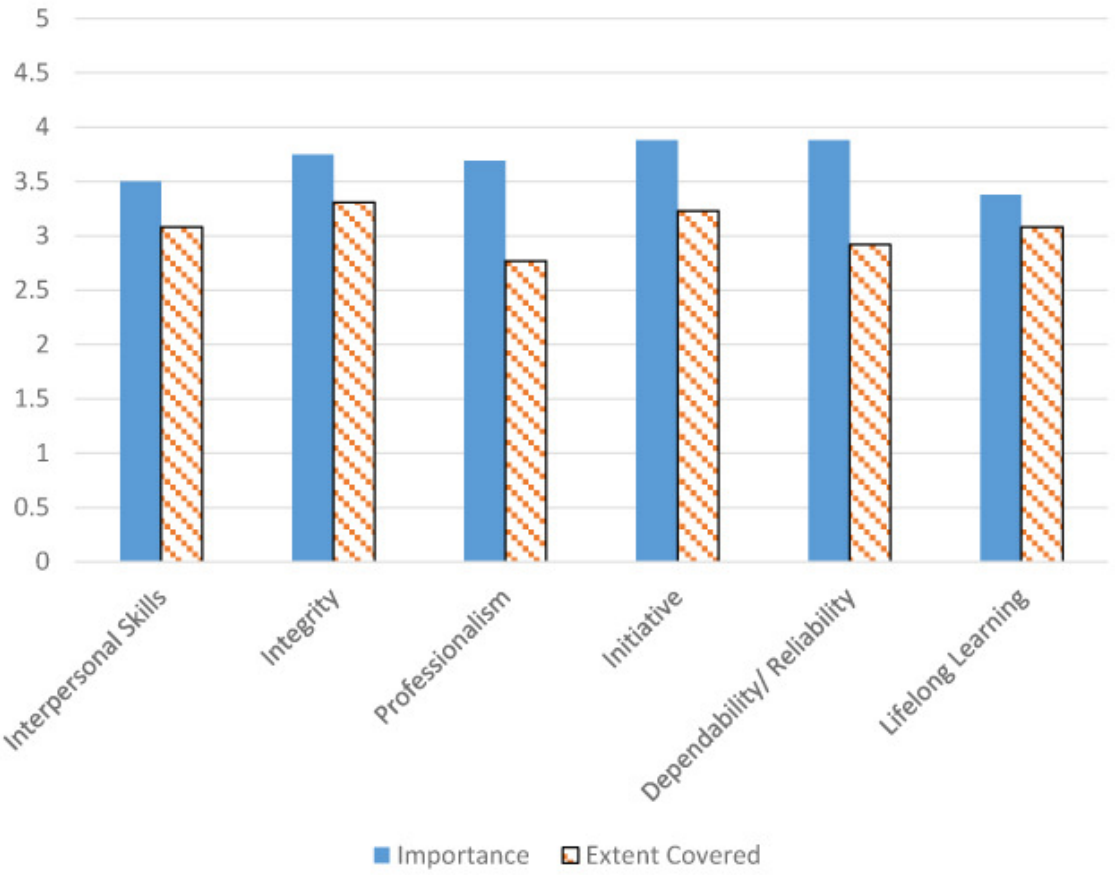

Figure 2: Personal Effectiveness Competencies Comparison of Importance to Extent Covered

For the academic competencies, respondents rated communication—listening and speaking as highest in importance with mathematics having the most coverage. Science was perceived lowest in importance and basic computer skills as least covered. See Table 2 and Figure 3.

Table 2: Academic Competencies Responses

	Perceived Importance		Extent Covered	
	Mean	Std Dev	Mean	Std Dev
Science: Knowing and applying scientific principles and methods to solve problems.	3.07	1.1	3.17	1.03
Basic Computer Skills: Using a personal computer and related applications to convey and retrieve information.	3.6	1.3	2.92	1.16
Mathematics: Using mathematics to solve problems.	3.27	0.96	3.58	0.79
Reading: Understanding written sentences and paragraphs in work related documents.	3.6	1.06	3.08	0.9
Writing: Using standard business English, defined as writing that is direct, courteous, grammatically correct, and not overly casual. The main requirement of workplace writing is clarity.	3.53	1.19	3	1.04
Communication—Listening and Speaking: Giving full attention to what others are saying and speaking in English well enough to be understood by others.	3.8	1.21	3.33	1.07
Critical and Analytical Thinking: Using logic, reasoning, and analysis to address problems.	3.73	1.16	3.33	0.65
Information Literacy: Functional and critical thinking skills related to information, media, and technology.	3.33	0.98	3.33	0.89

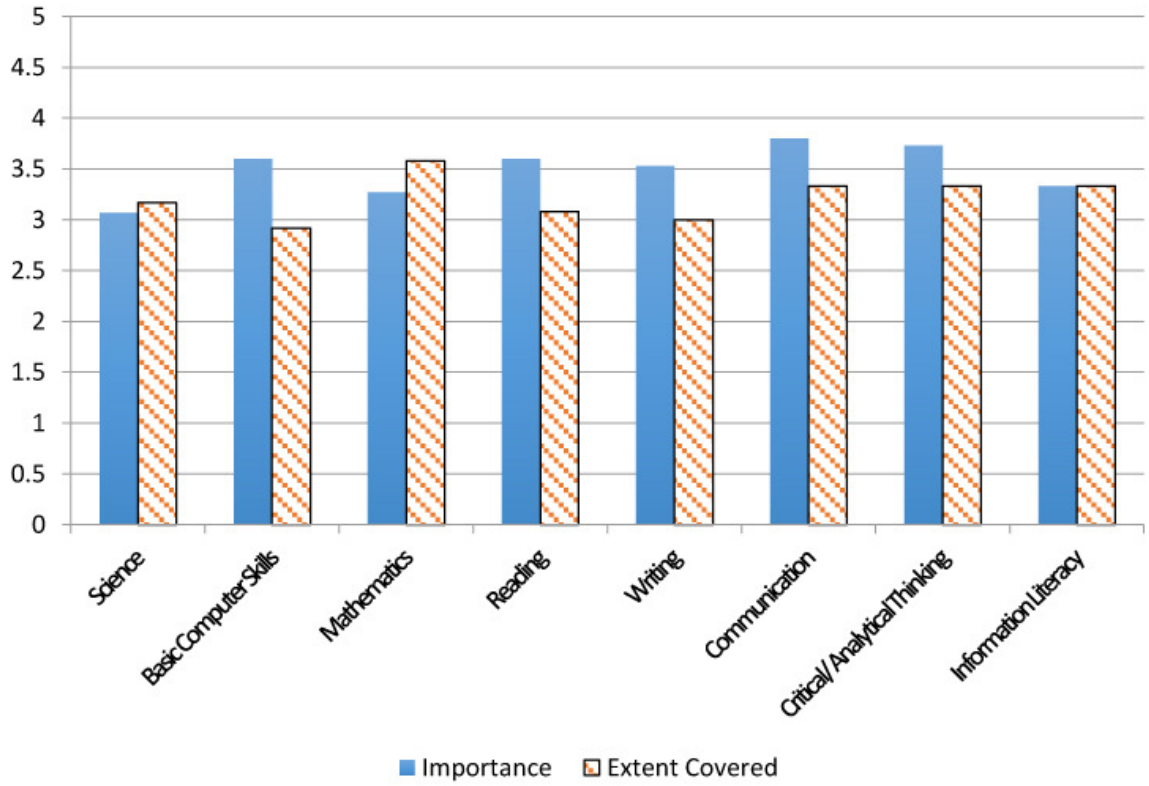

Figure 3: Academic Competencies Comparison of Importance to Extent Covered

In the workplace competencies, respondents rated problem solving and decision making highest in importance and teamwork as having the most coverage. Sustainable practices were perceived lowest in both importance and coverage. See Table 3 and Figure 4.
Table 3

Table 3: Workplace Competencies Responses

	Perceived Importance		Extent Covered	
	Mean	Std Dev	Mean	Std Dev
Business Fundamentals: Knowledge of basic business principles, trends, and economics.	3.13	1.06	3.25	1.06
Teamwork: Working cooperatively with others to complete work assignments.	3.93	1.22	3.75	0.97
Adaptability/Flexibility: Being open to change (positive or negative) and to considerable variety in the workplace.	3.93	0.96	3.15	0.9
Marketing and Customer Focus: Actively looking for ways to identify market demands and meet the customer or client need.	3.33	0.98	3	0.74
Planning and Organizing: Planning and prioritizing work to	3.93	0.88	3.25	0.62

manage time effectively and accomplish assigned tasks.				
Problem Solving and Decision Making: Applying critical-thinking skills to solve problems by generating, evaluating, and implementing solutions.	4.13	1.06	3.67	0.98
Working with Tools and Technology: Selecting, using, and maintaining tools and technology to facilitate work activity.	3.93	0.8	3.42	1
Checking, Examining, and Recording: Entering, transcribing, recording, storing, or maintaining information in written or electronic/magnetic format.	3.4	0.63	3.17	1.03
Sustainable Practices: Meeting the needs of the present without compromising the ability of future generations to meet their own needs.	3	0.85	2.75	0.75

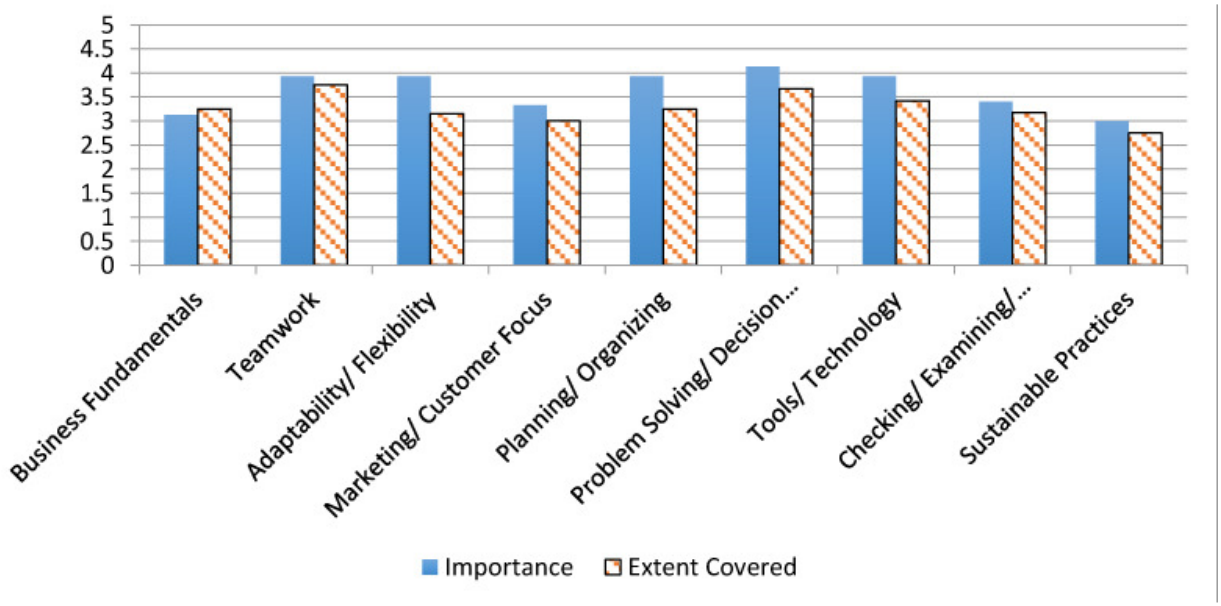

Figure 4: Workplace Competencies Comparison of Importance to Extent Covered

The last level surveyed was industry-wide technical competencies for the entry-level employee. Respondents perceived health, safety, security, and environment highest in importance and manufacturing process design and development as having the most coverage. Maintenance, installation, and repair was rated the lowest in both importance and coverage. Sustainable and green manufacturing was also rated least covered. See Table 4 and Figure 5.

Table 4: Industry-Wide Technical Competencies – Entry-Level Responses

	Perceived Importance		Extent Covered	
	Mean	Std Dev	Mean	Std Dev
Manufacturing Process Design/Development: Research,	3.43	1.22	3.64	1.21

design, implement, and continuously improve the manufacturing process to ensure product meets customer needs.				
Production: Set up, operate, monitor, control, and improve manufacturing processes and schedules to meet customer requirements.	3.64	1.22	3.27	1.01
Maintenance, Installation, and Repair: Maintain and optimize manufacturing equipment and systems.	3	1.18	2.91	0.83
Supply Chain Logistics: Plan and monitor the movement and storage of materials and products in coordination with suppliers, internal systems, and customers.	3.29	1.07	3	1.26
Quality Assurance and Continuous Improvement: Ensure product and process meets quality system requirements as defined by customer specifications.	3.79	0.97	3.45	1.21
Sustainable and Green Manufacturing: Manufacture products using processes that minimize negative environmental impacts; conserve energy and natural resources; are safe for employees, communities, and consumers; and are economically sound.	3.14	1.03	2.91	0.94
Health, Safety, Security, and Environment: Employ equipment, practices, and procedures that promote a healthy, safe, and secure work environment.	4.07	1.07	3.18	1.4

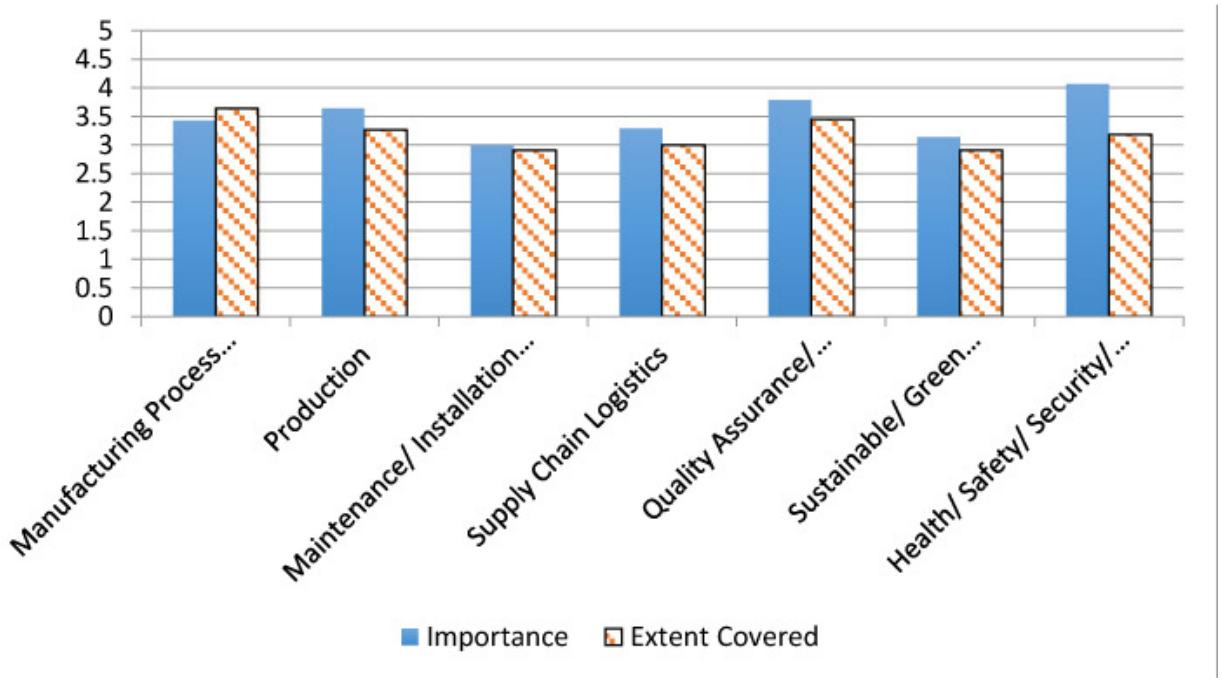

Figure 5: Industry-Wide Technical Competencies – Entry-Level Comparison of Importance to Extent Covered

The last question (question 9) asked the following. On a scale of 1 to 5 (with 5 being strongly agree and 1 being strongly disagree), indicate your perception of the following statement:

- Is the Advanced Manufacturing Competency Model compatible with what is being taught in your manufacturing program and the competencies that are important for an entry-level manufacturing professional?

Sixty-four percent of the respondents agreed or strongly agreed that the Advanced Manufacturing Competency Model is compatible with what is/was taught in their manufacturing program and that the competencies were important for an entry-level manufacturing professional. Fourteen percent disagreed. Twenty-one percent neither agreed nor disagreed. No respondent strongly disagreed with the statement. See Figure 6.

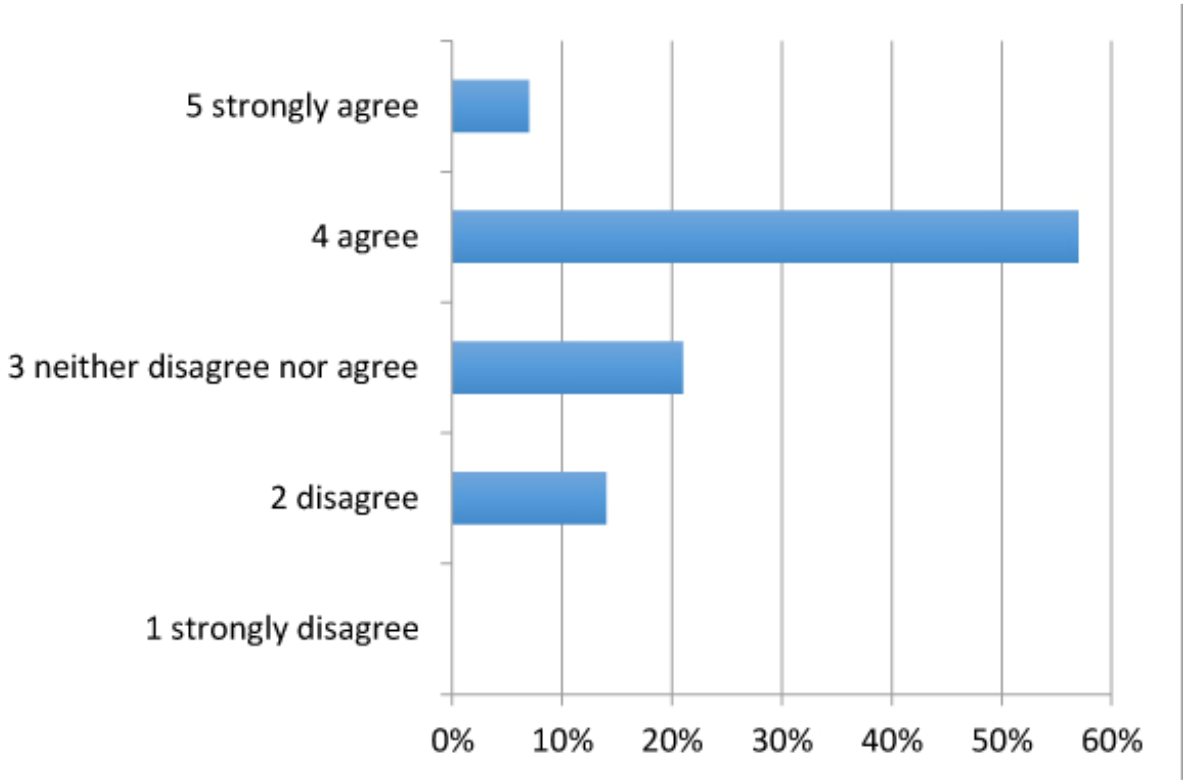

Figure 6: Percent of respondents who agree or disagree that the AMCM is compatible with their manufacturing program and the competencies important for an entry-level manufacturing professional.

Conclusion

For personal effectiveness, respondents perceived all competencies were of greater importance than the coverage received during their manufacturing program. Of particular interest was the disparity on professionalism, the maintaining of a socially acceptable

demeanor, which respondents rated second highest in importance, but lowest in coverage. Also noted was a difference in dependability and reliability, displaying responsible behaviors at work, which was one of the highest in importance and rated second lowest in coverage. These results may indicate the manufacturing program needs to reinforce all these competencies as part of the curriculum and pay greater attention to professional demeanors and responsible behaviors.

At the academic level, respondents perceived five of the eight competencies having greater importance than the coverage with two of the competencies having more coverage than importance. Information literacy importance matched coverage. Science and math were rated higher in coverage than importance. Of interest was the difference in basic computer skills, using a personal computer and related applications to convey and retrieve information. It was rated lowest in coverage, but high in importance along with communication, critical/ analytical thinking, and reading. These results may suggest that students are not as well prepared in computer literacy for the effective transfer of information. The result may also imply more attention should be paid to the reading and writing competencies, which could be related to general literacy and the processing of meaningful information into knowledge. If the basis for manufacturing programs is strong competency in math and science, a close corollary is communication—listening and speaking, a skill typically supported by an ability to read, write, and think well. Thus, the program may want to consider giving greater attention to reading, oral, and written communication.

In workplace competencies, respondents rated all higher in importance than coverage, except for business fundamentals. Of interest was the response to adaptability /flexibility, which is being open to change (positive or negative) and to considerable variety in the workplace. This was perceived one of the highest in importance, but lower in coverage. The next highest gap was in the perception of planning and organizing; the planning and prioritizing work to manage time effectively and accomplish assigned tasks. Curiously, these competencies may be two sides of the same coin as adaptability and flexibility are generally required when plans and organization do not occur as intended. The program may want to place more emphasis on work and time prioritization and managing change in the context of the other competencies.

For industry-wide technical competencies at the entry-level, respondents perceived slightly more importance than coverage for all competencies except manufacturing process design and development. The biggest gap in perception was in health, safety, security, and environment, which is the employment of equipment, practices, and procedures that promote a healthy, safe, and secure work environment. Respondents rated this highest in importance, but one of the lowest in coverage. The manufacturing program may want to add more content to existing courses for safety, ergonomics, and the environment.

Almost two-thirds of the respondents agreed that the Advanced Manufacturing Competency Model is compatible with what is being taught in the manufacturing program and the competencies that are important for an entry-level manufacturing professional. Contrarily, slightly over one-third of the respondents neither agreed nor disagreed or disagreed with the

statement. This may indicate that the current perceived gaps between importance and coverage of the advanced manufacturing competencies could be narrowed and potentially produce better prepared entry-level manufacturing professionals.

In summary, an increased emphasis on professionalism and responsible behaviors with greater attention to thinking, reading, oral, and written communication might improve academic performance and personal effectiveness. In terms of competencies that would benefit respondents in the manufacturing workplace, the program should consider increased attention to planning and organizational skills coupled with lessons on adaptability. Finally, the program should evaluate if a greater amount of content on equipment, practices, and procedures that promote a healthy, safe, and secure work environment would be beneficial. Overall, for this manufacturing program, the Advanced Manufacturing Competency Model was perceived compatible with the important and taught competencies for an entry-level manufacturing professional.

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Biographies

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