Manufacturing

Perceptions of Manufacturing Management Knowledge and the Four Pillars Topical Track: Manufacturing

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Introduction

In June 2011, a group of manufacturing educators in cooperation with the Society of Manufacturing Engineers (SME) developed Curriculum 2015, a four-year strategic plan to reverse negative trends in manufacturing education and improve manufacturing competitiveness. Within this effort, the Four Pillars of Manufacturing Engineering were formally introduced and supported by the Society of Manufacturing Engineers (SME), the Association of Technology, Management, and Applied Engineering, (ATMAE), and the Accreditation Board for Engineering and Technology (ABET). The Four Pillars consist of foundational areas that represent the SME Certified Manufacturing Engineer Body of Knowledge. It embodies the fundamental knowledge practiced by manufacturing professionals and is the recommended content for academic programs related to manufacturing. One of its foundational areas is manufacturing management.

Management curriculum is what distinguishes four-year manufacturing programs from two-year programs across ATMAE accredited programs. It also distinguishes the discipline from traditional engineering programs. The required knowledge and competencies for an entry-level manufacturing manager are important. Hence, these competencies and knowledge sets should be well understood and agreed-upon by ATMAE accredited manufacturing program faculty and students.

Manufacturing education should provide excellent training and prepare students for entry-level positions in industry. The interests of students and faculty in manufacturing education strongly affect how well they are prepared to meet the challenges in industry. This research sought to capture the perceptions of an ATMAE accredited manufacturing program. Alumni, students and faculty of the program were surveyed regarding the Four Pillars manufacturing foundational areas and the knowledge required for entry level manufacturing managers. Specifically, the research addressed the following:

- What fundamental knowledge is most important for an entry-level manufacturing manager?
- What fundamental knowledge is comprehensively covered in manufacturing education programs?

- Is the manufacturing management knowledge specified by the Four Pillars model congruent with what is being taught and what is perceived as important for an entry-level manufacturing manager?

Literature Review

According to the Manufacturing Institute (2010), manufacturing is critical to economic security since it pays wages higher on average than other industries, creates the highest number of jobs directly and indirectly, and contributes to more than 50 percent of total U.S. exports. The critical nature of manufacturing to economic security infers that it is critical to national security as well given that a vibrant and innovative manufacturing base underpins defense and homeland security. Advocates of manufacturing promote competency-based education and industry-education partnerships to ensure that schools teach the latest skills required by industry. Efforts are now starting at making manufacturing attractive to talented skilled workers.

The shortage of skilled workers to fill positions in manufacturing indicates that manufacturing is facing a crisis. The reduction in investments, interest, and support for Science, Technology, Engineering, and Mathematics (STEM) fields have also had a negative impact. The existence of a skills gap between what manufacturers want and the available skills in the workforce has been a hindrance to hiring and has created an inability to fill job openings even during the recession (Morrison et al., 2011). However, a renewed interest in reviving manufacturing competiveness as a way to turn around current economic conditions has provided opportunities for manufacturing education. Recommendations include equipping students with strong STEM foundations, consistent manufacturing curricula, and faculty development (Society of Manufacturing Engineers, 2012).

According to Mott, Jack, Raju, & Stratton (2011) 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 any other entity. The authors suggested that the Four Pillars could prove useful in addressing the gaps in existing programs, as it would require the development of materials for use in classrooms, laboratories, and design projects in order to be disseminated appropriately.

Manufacturing Knowledge and Skills

Sullivan (2012) conducted a study to understand what skills manufacturers seek most in hiring college graduates. The researcher found a shift in focus from the traditional skill set of engineering curricula to those that emphasize people skills and an understanding of cross-functional relationships between disciplines. The study also showed that manufacturers are increasingly placing an emphasis on outside certifications in an attempt to reduce in-house training costs. Overall, manufacturers look toward academic institutions to provide employees with a suitable combination of human skills, work experience, and technical competence. However, the needs of industry are not only about new graduates, but also about the need to maintain the skills and competencies of experienced engineers and technologists. New manufacturing technologies should be investigated to ascertain how they could influence future education and training (Raju, 2010).

Hamidizadeh & Farsijani (2008) explored how traditional factors of production such as land, labor, and capital are increasingly becoming restraining forces rather than driving forces as necessary elements for attaining competitive manufacturing. In their opinion, a focus on knowledge management as a driver of manufacturing operations would prove more useful in transforming the culture of organizations. It is important to develop the personal knowledge and social capabilities of employees in order to improve their innovative and creative capabilities towards the achievement of world-class manufacturing practices.

Lahidji and Albayyari (2002) asserted that globalization and rapid improvements in technology are indicators of the need for knowledgeable and competent workers. Accordingly, industries desire engineers whose appreciation of manufacturing will enable them apply their knowledge productively. The competencies acquired in manufacturing engineering programs should emphasize knowledge and skills that help graduates work effectively in a diverse workforce. Programs should emphasize competencies such as human factors, ergonomics, ethics, engineering law, cultural diversity, technology, and environmental issues.

According to Rodriguez, de Ciurana, and Elias (2005), industry-university cooperation provides benefits for both parties such as the integration of multiple heterogeneous manufacturing technologies and the development of project management and communication skills. In addition, students have opportunities to cultivate an industrial frame of mind, while industry has the opportunity to train potential employees. Other forms of manufacturing curricula cited by researchers included learning laboratories as a complement to traditional teaching (Platts, 2004), supplemental hands-on activities for classrooms, manufacturing systems training for high school faculty (Fonseca, Whitaker, Driver, & Boman, 2011), and the promotion of advanced manufacturing knowledge as a source of sustainable competitive advantage (Sanchez & Palacios, 2008).

Lowden, Hall, Elliot, & Lewin (2011) 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 the development of programs to promote and recognize experiential and work-related learning.

The applied learning aspect of technology management is a distinctive characteristic of ATMAE accredited manufacturing programs. Knowledge of manufacturing management and an understanding of the manufacturing competencies that are most important should be evident in students, alumni, and faculty of manufacturing programs. This research sought to capture that knowledge and the perceptions of an ATMAE accredited manufacturing program.

Research Method

A pilot survey instrument was created to capture the perceptions of faculty, students, and alumni associated with an ATMAE accredited advanced manufacturing program. Program faculty and alumni at the annual advisory board meeting conducted an initial review of the survey for face validity. The survey listed 32 items from the Four Pillars of Manufacturing Engineering model, of which 14 were the foundation items of manufacturing management. The other 18 items were selected from each of the other foundational areas of the model, except mathematics and science, as these are required for all majors in the college. Respondents were asked to rate each item twice using a Likert scale from 1 to 4. No accommodation for a "not applicable" response was given. However, respondents could choose to ignore the item. On the first question set, respondents ranked the degree they perceived the item's importance with 4 being very important and 1 being not important. In the second question set, the respondents ranked the degree they perceived the item was/is covered in the manufacturing program. A response of 4 indicated the item was covered comprehensively with 1 representing no coverage.

Once the instrument was validated, a graduate assistant converted the survey into the electronic survey software Qualtrics, an institutionally approved survey package. The population of participants was selected because of their expertise and involvement in manufacturing and manufacturing management. Invitations were sent in the spring semester via email to all current manufacturing students and faculty in the program. A second request was sent eight days later with a final request sent seven days thereafter. The invited students included both graduate and undergraduate levels. The total survey population was approximately 160 students, 9 faculty, and 12 alumni. The total number of survey responses was 52, a response rate of approximately 28%. All collected responses were anonymous. The data was compiled, sorted, and analyzed using descriptive statistics. A t-test was conducted to compare the means of the two question sets.

Findings

Figure 1 presents the summary of the survey results for the two question sets asked during the survey. The bar chart shows the mean values of the survey questions for 32 key knowledge topics selected from the manufacturing management area of SME Four Pillars model. The top five ratings for each survey are shown in boldface. A comparison of the mean difference between the responses for the question 1 set (importance) and question 2 set (coverage) was significant ($t(62) = 5.81$, $p < .001$) assuming equal variances.

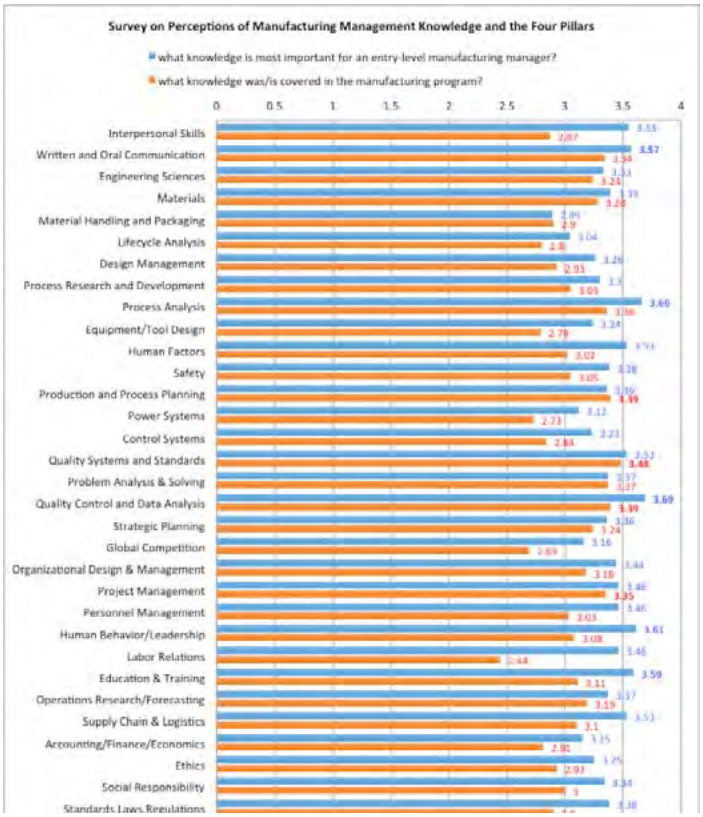

Figure 1. Bar chart showing the mean value of ratings for 32 Four Pillars key topics in response to the two questions sets

Question 1: Of the following, what knowledge is most important for an entry-level manufacturing manager? For each one, please indicate degree of importance on a scale of 1 to 4 (1 being "Not Important" to 4 being "Most Important")

Most of the respondents perceived the items (31 out of 32) to be important (ratings higher than 3) for an entry-level manufacturing manager position. The top five items perceived to be most important were quality control and data analysis (3.69), process analysis (3.66), leadership skills (3.61), education and training (3.59) and written/oral communication (3.57). Quality control was perceived to be the most important technical area for a managerial position. The other important technical areas were supply chain and logistics (3.53), quality systems and standards (3.53), and human factors/ergonomics (3.53). On the other hand, the least rated five items for question 1 (important knowledge for entry-level manufacturing manager) were material handling and packaging (2.89), life cycle analysis (3.04), power systems (3.12), accounting/finance/economics (3.15), and global competition (3.16).

Question 2: Of the following, what knowledge was/is covered in the manufacturing program? For each one, please indicate degree of coverage on a scale of 1 to 4 (1 being "Not Covered" to 4 being "Covered Comprehensively")

For the second survey question on how those items are or were covered in the manufacturing program curriculum, the survey results indicated that above-mentioned top five items are covered quite comprehensively. The survey results showed rankings higher than 3 for all five items: quality control and data analysis (3.39), process analysis (3.36), leadership skills (3.08), education and training (3.11) and written/oral communication (3.34). Thus, the program is perceived as covering the most important items adequately. The top six items perceived as covered most comprehensively were quality systems and standards (3.48), quality control and data analysis (3.39), production and process planning (3.39), problem analysis and solving (3.37), process analysis (3.36) and project management (3.35). Among all the 32 items, the least rated five items perceived as not covered in the current curriculum were labor relations (2.44), global competition (2.69), power systems (2.73), equipment and tool design (2.79), and life cycle analysis (2.8). However, according to the participants, not all of these five items are important. Among these five items, labor relations was rated the 12th most important (3.46) of the 32 items.

Conclusions

The survey results reveal that for an entry-level manufacturing manager, the professional or non-technical skills, such as leadership and communication skills are perceived to be as important as technical skills. Thus, a manufacturing manager needs various professional and/or non-technical skills in addition to technical skills. Therefore, manufacturing education programs should strongly consider including these skill sets in the curriculum or through extra-curricular activities. The most important items that were rated as not being covered comprehensively in the curriculum were human behavior/leadership, interpersonal skills, human factors, and labor relations.

Among the technical items, knowledge on quality control and data analysis and process analysis were perceived as most important for an entry-level manufacturing manager. This finding may also suggest that a majority of the manufacturing program graduates obtain entry-level positions related to these areas. The participants perceived that quality systems and standards, production and process planning are well covered in the manufacturing program. However, the survey results suggested that the program might need to evaluate the level of coverage for material handling and packaging and standards, laws, and regulations, which participants rated higher in importance compared to the perceived level of coverage. Revising other technical topics and/or related courses such as production and process planning may need to be given less emphasis and/or revised based on current perceptions.

A possible limitation of this survey was the higher values of standard deviation for almost each of the 32 items. It can be seen that the standard deviation ranges from 0.7 – 1.0 for the topics selected for the survey responses of both questions. For all the 32 items, the ratings range from 1 to 4 in response to both questions.

Future Research

The authors believe that this survey research could be very useful to similar manufacturing programs, i.e., manufacturing technology, manufacturing engineering technology etc., in other universities. Therefore, researchers should conduct a more comprehensive study among faculty and students of similar ATMAE accredited programs. In addition, ATMAE industry partners could be invited to participate. A revision of the survey content and process to suit a large number of participants would be appropriate. Future studies should also encourage comments to provide additional insight into perceptions. The comments would provide useful qualitative information for evaluating curriculum and the competencies needed by an entry-level manufacturing manager. The results and findings of a more comprehensive study should be disseminated to all the participating institutions and ATMAE leadership, including the boards of accreditation and certification for consideration.

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Appendices

Table A1

What knowledge is most important for an entry-level manufacturing manager?

Topic	Mean	SD	Responses
Quality Control and Data Analysis	3.69	0.74	32
Process Analysis	3.66	0.79	32
Human Behavior/Leadership	3.61	0.83	28
Education & Training	3.59	0.71	32
Written and Oral Communication	3.57	0.73	30
Interpersonal Skills	3.55	0.78	29
Human Factors	3.53	0.88	32
Quality Systems and Standards	3.53	0.78	30
Supply Chain & Logistics	3.53	0.75	40
Project Management	3.46	0.93	24
Personnel Management	3.46	0.88	28
Labor Relations	3.46	0.81	41
Organizational Design & Management	3.44	0.87	41
Materials	3.39	0.81	44
Safety	3.38	1.02	16
Standards, Laws, Regulations	3.38	0.85	34
Problem Analysis & Solving	3.37	0.9	19
Operations Research/Forecasting	3.37	0.72	43
Production and Process Planning	3.36	0.95	25
Strategic Planning	3.36	0.82	33
Social Responsibility	3.34	0.83	32
Engineering Sciences	3.33	0.81	39
Process Research and Development	3.3	0.88	37
Design Management	3.26	0.98	38
Ethics	3.25	0.99	24
Equipment/Tool Design	3.24	0.82	42
Control Systems	3.23	0.93	39
Global Competition	3.16	0.93	45
Accounting/Finance/Economics	3.15	0.92	46
Power Systems	3.12	0.94	42
Lifecycle Analysis	3.04	0.95	45
Material Handling and Packaging	2.89	0.86	45

Table A2
What knowledge was/is covered in the manufacturing program?

Topic	Mean	SD	Responses
Quality Systems and Standards	3.48	0.87	33
Production and Process Planning	3.39	0.79	33
Quality Control and Data Analysis	3.39	0.88	28
Problem Analysis & Solving	3.37	0.94	35
Process Analysis	3.36	0.84	39
Project Management	3.35	0.85	26
Written and Oral Communication	3.34	0.71	44
Materials	3.28	0.91	46
Engineering Sciences	3.24	0.82	46
Strategic Planning	3.24	0.86	37
Operations Research/Forecasting	3.19	0.92	42
Organizational Design & Management	3.18	0.87	34
Education & Training	3.11	0.95	38
Supply Chain & Logistics	3.1	1.04	31
Human Behavior/Leadership	3.08	0.97	40
Process Research and Development	3.05	0.89	39
Safety	3.05	0.91	37
Personnel Management	3.03	1.07	35
Human Factors	3.02	0.95	42
Social Responsibility	3	0.83	45
Design Management	2.93	0.94	40
Ethics	2.93	0.96	41
Material Handling and Packaging	2.9	0.97	48
Standards, Laws, Regulations	2.9	0.97	39
Interpersonal Skills	2.87	0.92	47
Control Systems	2.84	1.01	37
Accounting/Finance/ Economics	2.81	1.01	43
Lifecycle Analysis	2.8	0.9	44
Equipment/Tool Design	2.79	1.06	47
Power Systems	2.73	1.05	41
Global Competition	2.69	0.97	48
Labor Relations	2.44	0.92	45