



2013 State of Manufacturing Education

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Abstract

This paper presents the 2013 results of an annual survey of manufacturing educators and professionals. The survey results are compared to results from previous years, and the trends discussed. The data in the surveys include general attitudes about manufacturing education, underserved topics, and general comments from the educators. This paper will also include a limited set of observations and recommendations.

1. Introduction

Many recent reports have examined manufacturing education and its relationship to manufacturing practice. Two notable examples include the Curricula 2015¹, and the SME Workforce Imperative: A Manufacturing Education Strategy². The key point in a majority of these reports is that the demand for manufacturing skills and knowledge exceeds the education supply. The reason for the gap is multifold including a small number of students focusing on manufacturing related studies, new technologies, new curriculum, economic trends, and socio-political priorities. This paper is part of a multi-year body of work intended to document the state of manufacturing education from the perspective of individual educators and practicing professionals.

This paper documents the fourth annual survey of manufacturing educators and practitioners. The purpose of the survey is to capture the overall sense of the community about manufacturing education in general, and the relevance of the curriculum. The survey questions and format have been kept very similar to allow comparison of data across multiple years. Reports from surveys in previous years are available from the freely accessible ASEE paper database^{3,4,5}. Results from the 2012 and 2011 surveys are presented in this paper for comparison.

2. The Survey

The strategy used for the survey is to provide a limited number of questions that can be answered in a few minutes. This does result in a loss of subtlety, but it also increases the response rate. Comment responses are used to capture other opinions not addressed in the brief survey. In this form the comments serve as anecdotal evidence of trends and opinions. As such they are used for discussion and may have an effect on future versions of the survey.

The survey was prepared and distributed using a Google Form. Respondents completed the form on a single page, and once submitted the results were automatically entered into a spreadsheet. The survey responses are anonymous unless a name is entered in the comments fields.

The survey was distributed to large group based on ETD list serve, ASEE manufacturing division, participation in past manufacturing education events, etc. Combination of academics and practitioners. The estimated distribution group size was 2,000 relevant recipients, making the response rate approximately 10%.

3. Demographics

There were 212 unique respondents to the survey. The survey asked respondents to identify their current role as related to manufacturing. Table 1 shows that 96 identified themselves as an Educator. The table suggests a total of 99 practitioners are counted as the Consultants (9), Managers (38), and Technical (47).

Table 1 - Responses to “Your Current Role”

Your Current Role	No.	% 2013	% 2012	% 2011
Consultant	9	4%	7%	7%
Educator	96	47%	33%	39%
Manager	38	19%	25%	20%
Student	1	0%	1%	2%
Technical	47	23%	27%	27%
Other	9	4%	3%	4%

Table 2 shows the results from a question about the respondent’s employer. Notably there are 110+1 listed as employed in education. This is greater than the 96 educators identified in Table 1. The numerical difference can be largely explained using non-teaching staff including administrators, researchers, and technicians. The 110 Educators are identified as Academics in following discussions. The number of 80 practitioners is estimated to include Manufacturers (67), Self Employed (11), and Support Company (2).

The Academic/Practitioner division is used for various data sets to compare perspectives. It is worth observing that while the groups are cleanly identified, individuals in these groups may

play multiple roles. However, the size of the groups is large enough to provide a level of statistical significance.

Table 2 - Responses to ‘Your Employer’

Your Employer	No.	% 2013	% 2012	% 2011
College or University	110	54%	43%	45%
K-12 School	1	0%	0%	0%
Manufacturer	67	33%	40%	41%
Self Employed	11	5%	6%	4%
Support Company - e.g., training, consulting	2	1%	3%	2%
Support Organization - eg., SME, NSF, NAE	1	0%	0%	1%
Other	10	5%	5%	5%

Table 3 shows the reported length of activity in manufacturing careers. The distribution is relatively even suggesting that the survey reached a broad audience. However, the number of respondents in the first ten years of their careers has decreased substantially. In comparison with the numbers in 2012 and 2011 there appears to be a substantial reduction in the number of early career manufacturing professionals.

Table 3 - Answers to “Years in Manufacturing”

Years In Manufacturing	Number 2013	Number 2012	Number 2011
0-4	24	44	50
5-9	24	35	50
10-14	33	36	33
15-19	29	22	18
20-24	21	22	31
25-29	21	15	22
30-40	38	22	34
40+	12	10	16

Recommendation: Assess the number of young professionals entering manufacturing careers.

4. The Sense of the Community

The general outlook of the manufacturing education interest groups is gauged with a set of five questions. The results for practitioners and academics are presented separately to highlight the differences in perspective. Results for the previous surveys are also provided to illustrate trends.

In the coming years do you believe that US manufacturing and manufacturing education will.....

Help the economy	2013					2012					2011		
	Disagree	Slight Disagree	Neutral	Slight Agree	Agree	Disagree	Slight Disagree	Neutral	Slight Agree	Agree	Disagree	Neutral	Agree
Overall	3	2	6	<u>39</u>	151	3	1	6	<u>18</u>	151	3	11	158
Educators	1	2	0	15	78	0	1	3	7	74	2	5	75
Manufacturers	2	0	5	22	63	0	0	3	9	53	1	2	53

Be a political priority	2013					2012					2011		
	Disagree	Slight Disagree	Neutral	Slight Agree	Agree	Disagree	Slight Disagree	Neutral	Slight Agree	Agree	Disagree	Neutral	Agree
Overall	13	25	30	<u>86</u>	48	11	17	<u>56</u>	36	45	25	<u>52</u>	48
Educators	6	8	11	44	27	5	7	18	24	26	11	16	25
Manufacturers	5	16	17	37	18	3	9	26	8	12	6	27	15

Be a social priority	2013					2012					2011		
	Disagree	Slight Disagree	Neutral	Slight Agree	Agree	Disagree	Slight Disagree	Neutral	Slight Agree	Agree	Disagree	Neutral	Agree
Overall	15	36	61	<u>61</u>	29	9	24	58	<u>36</u>	29	23	65	33
Educators	5	22	28	26	15	5	12	17	23	15	12	22	16
Manufacturers	9	12	28	<u>33</u>	11	3	9	31	<u>11</u>	5	8	33	10

Have a better image	2013					2012					2011		
	Disagree	Slight Disagree	Neutral	Slight Agree	Agree	Disagree	Slight Disagree	Neutral	Slight Agree	Agree	Disagree	Neutral	Agree
Overall	10	16	53	<u>86</u>	36	7	16	38	<u>53</u>	43	14	66	31

Educators	5	11	22	39	19	3	11	13	28	20	10	26	15
Manufacturers	5	3	27	<u>43</u>	14	3	4	19	<u>15</u>	16	4	26	10

Improve education and industry ties	2013					2012					2011		
	Disagree	Slight Disagree	Neutral	Slight Agree	Agree	Disagree	Slight Disagree	Neutral	Slight Agree	Agree	Disagree	Neutral	Agree
Overall	8	6	30	<u>88</u>	68	2	6	34	<u>40</u>	75	6	57	66
Educators	3	4	11	42	34	0	3	14	19	39	4	23	29
Manufacturers	5	2	18	42	26	2	3	15	12	24	2	25	21

There is strong belief from academics and practitioners that manufacturing helps the economy, and the opinion has not changed significantly over the three years. Although it is worth noting that some of the support has slipped from ‘agree’ to ‘slightly agree’. If this becomes a trend then we may see a loss of confidence and loss of enthusiasm. Valid, or not, it suggests the need for an informed discussion about the role of manufacturing in the economy.

Recommendation: Assess and disseminate the role of manufacturing in the economy.

There is a clear increase in the belief that manufacturing will become a political priority. This may be the result of some substantial announcements in 2012 related to the Advanced Manufacturing Initiative⁶. In practical terms this will probably translate to favorable changes to manufacturing education funding.

On the issue of the social priority of manufacturing education, there is an overall increase in 2013. Interestingly, the numerical increase is the product of manufacturing practitioners. A similar trend is seen for the image of manufacturing question. This raises the question about why the practitioners sense an improvement while the educators do not? Are the practitioners in a position to attract more people to manufacturing careers?

Recommendation: Investigate the changes in public perceptions about manufacturing.

The question about improving ties between industry and academia shows a large increase in the ‘slightly agree’ category. It appears that the interest, and possibly willingness, in cooperation. This suggests that there is a growing opportunity for academic-industry cooperation. What these could be is not clear from the question but it could include research, student projects, co-ops, funding, and curriculum review.

Recommendation: Develop new initiatives between industry and academics.

5. The Manufacturing Sector and Processes Priorities

Emerging, and underserved, industry needs were identified by two questions that asked for greatest, and second greatest needs. It is recognized that asking for the top two priorities ignores many other subtle details. Moreover, any topic in the curriculum that is well taught, and essential, may not receive any votes. One alternative would be to rank the topics from top to bottom, but the added time to complete the survey would reduce the response rate. Another alternative used in the past was to assign an importance score on a scale. However, survey respondents normally list many topics as highly important and the differentiation is lost. Therefore, asking for the top two choices are used as a compromise for a fast survey response. And, the results cannot be used to identify topics for reduction, or elimination.

Table 4 shows the number of respondents selecting each industry sector as the top and second priority. These are also broken into academic and practitioner top priorities, to highlight the differences. Results from 2012 and 2011 are presented for comparison.

Table 4 - Manufacturing Sectors and Processes Priorities

Topics	2013				2012		2011	
	Top Priority	Second Priority	Educators Top Priority	Manufacturers Top Priority	Top Priority	Second Priority	Top Priority	Second Priority
** Additive processes	16	12	9	6	4	8	3	8
Aerospace	2	6	1	1	6	4	3	4
Alternative energy	26	23	9	16	38	25	73	33
Assembly and joining	4	8	2	2	10	9	4	9
Automotive	12	8	5	7	16	10	7	18
Biomedical	26	14	9	13	24	24	41	39
Casting	1	0	1	0	2	1	0	1
Electronics	19	18	5	14	17	20	13	20
Finishing and coating	0	1	0	0	0	1	0	2
Forming and fabricating	7	11	3	4	7	10	12	12
Heavy equipment	1	1	1	0	0	1	1	1
Material removal	8	3	6	2	3	9	7	1

Materials processing	12	28	7	4	12	17	20	18
Nanotechnology	11	20	7	4	23	28	19	39
Plastics and composites	9	10	6	3	8	22	10	18
Production equipment and tooling	27	18	10	14	26	11	26	17
Welding and cutting	1	4	1	0	2	3	0	0

Traditional manufacturing sectors such as casting, heavy equipment, finishing, coating, welding, cutting were rarely selected, indicating that there is a reasonable level of satisfaction with current offerings. A number of observations are listed below. These observations were developed using overall counts, differences over time, and differences between academics and practitioners. The priority of:

- Additive processes have a sudden increase in interest.
- Alternative energy is high, but decreasing.
- Biomedical energy is high, but decreasing slowly.
- Electronics remains high.
- Materials Processing remains high.
- Nanotechnology is high, but decreasing.
- Plastics and composites is decreasing.
- Production equipment and tooling is high.

The areas with decreasing interest indicate that progress has been made in addressing the needs. For example, the decrease in priority indicates that Alternative Energy, Biomedical, Nanotechnology, and Plastics and Composites initiatives are making an impact and should continue. This impact may increase as the successful curriculum is disseminated to other programs.

Recommendation: Continue efforts to address Alternative Energy, Biomedical, Nanotechnology, and Plastics and Composites.

Areas with a high priority and no significant decrease include Electronics, Materials Processing, and Production Equipment and Tooling. The lack of change in priority indicates that not enough is being done to address the issues. This may be a lack of effort overall, or the need for a new and innovative approach. The sudden increase in the priority of Additive Processes indicates an opportunity to get ahead of the need.

Recommendation: New efforts are required for Electronics, Materials Processing, and Production Equipment and Tooling.

Recommendation: Innovators will prepare for additive manufacturing now.

6. Curriculum Priorities

The next survey question dealt with the topics that form courses and threads in a curriculum. As before the respondents were asked for their top two priorities. The results are shown in Table 5 for the top two choices, the choices for academics and practitioners, and for the last two years.

Table 5 - Study Topics Priorities

Topic	2013				2012		2011	
	Top Priority	Second Priority	Educators Top Priority	Manufacturers Top Priority	Top Priority	Second Priority	Top Priority	Second Priority
Advanced processes	16	12	11	4	25	18	23	18
Advanced theoretical methods	1	4	0	1	5	6	1	3
Automation and controls	33	19	16	17	36	19	36	22
Basic science and mathematics	11	3	3	8	16	6	18	8
Basic processes	11	6	5	5	5	6	12	9
Business and management	9	8	4	3	8	10	11	15
CAD/CAM	17	14	10	7	12	11	22	13
Communication	4	6	0	3	4	5	5	10
Circuits	3	3	2	1	2	5	3	2
Costing and economics	5	9	0	4	3	9	4	11
Ethics and professionalism	4	7	1	3	3	5	4	7
Instrumentation and metrology	2	2	1	3	3	5	2	6
Lean manufacturing	26	25	13	11	20	22	26	32
Materials science	11	10	8	0	10	10	10	15
Mechanics and solids	2	4	2	0	2	10	7	6
Production modeling and layout	1	12	1	0	7	8	3	7

Product design	20	19	9	11	28	23	35	32
Quality and statistics	9	17	4	4	7	15	13	15
Sustainability	10	14	5	4	9	14	15	14
Thermo-fluid sciences	1	0	0	1	0	1	1	7

The results show that the general attitude is that the fundamentals are not a high priority, suggesting that they already serve the curriculum well. Examples of these include Thermo-fluids, mechanics, circuits, etc. Other topics received a high number of priority rankings, suggesting that these require additional consideration, or new developments.

Topics that have constant, and high, demand include Automation and Controls, CAD/CAM, and Lean Manufacturing. The constantly high demand means that there has been little success in addressing these needs. Given that there is little difference between the academic and practitioner opinions the problems are not based in a lack of interest, other factors must be involved.

Recommendation: Apply new and innovative efforts to address Automation and Control, CAD/CAM, and Lean Manufacturing in the curriculum.

Areas with a high, but decreasing demand include Advanced Processes, Basic Science and Mathematics, Materials Science, and Product Design. This reflects the success of various groups in addressing these needs. Naturally these efforts that have begun in these areas should continue.

Recommendation: Continue curriculum development work in Advanced Processes, Basic Science and Mathematics, and Product Design.

Areas with lesser priority and no obvious up/down trends include Basic Processes, Business and Management, Costing and Economics, Quality and Statistics, and Sustainability. Given the right circumstances these provide areas for leadership and dissemination.

Recommendation: Consider conference activities to discuss and share good practices in Basic Processes, Business and Management, Costing and Economics, Quality and Statistics, and Sustainability.

7. Education Methods

Methods used for teaching and learning were the subject of the last question. Respondents were asked to rate the top two priorities for education methods. The results for 2013 are subdivided for

the academics and practitioners. Previous top choices for 2012 and 2011 are also presented in Table 6.

Table 6 - Education Method Priorities

Method	2013				2012		2011	
	Top Priority	Second Priority	Academics Top Priority	Manufacturers Top Priority	Top Priority	Second Priority	Top Priority	Second Priority
Certifications	9	10	5	3	13	8	7	8
Communication	6	4	1	5	3	7	3	8
Co-op or internship	60	31	16	39	63	39	69	35
Distance education	5	8	3	2	5	6	12	10
Global study or travel	4	12	2	1	3	9	6	13
Graduate studies	10	2	7	2	8	10	7	11
Laboratory work	17	24	15	1	19	19	30	29
Liberal education	3	4	0	3	2	2	3	5
Newer technologies	13	18	4	8	25	32	22	26
Project and design work	59	46	36	20	50	41	67	57
Self directed learning	2	14	0	2	8	12	15	12
Seminars	1	1	1	0	2	0	0	1
Teamwork	7	22	3	3	7	22	6	30

Co-operative education and internships continue to be the overwhelming priority for practitioners, and this is echoed supported by academics. In a complimentary sense, project and design work is favored by academics, and practitioners second that opinion. Laboratory and Teamwork also receive special mention. In total these illustrate the importance of education that includes exploration in the lab, through projects, and in the workplace. Given the widespread agreement, the question is not ‘if we should’, but ‘how should we’?

Recommendation: Explore new methods for education that involves work in laboratories, projects, and workplaces.

8. Conclusions

In general the community is positive about the value of manufacturing education, but continues to perceive a lack of social and political support. There are signs that manufacturing practitioners are more positive than educators about manufacturing in general. This is reasonable given the ongoing economic recovery.

References

1. Hugh Jack et al. "Curricula 2015: A Four Year Strategic Plan for Manufacturing Education," June 2011. Available from <http://www.C2015.com>.
2. Bennett, R., et al. "Workforce Imperative: A Manufacturing Education Strategy", Society of Manufacturing Engineers, September 2012. Available from <http://www.sme.org/WorkforceImperative/>.
3. Jack, H., "Perceptions in the Manufacturing Education Community", ASEE Annual Meeting, Louisville, KY, June 2010.
4. Jack, H., "The 2011 State of Manufacturing Education", ASEE Annual Meeting, Vancouver, BC, June 2011.
5. Jack, H., "The 2012 State of Manufacturing Education", ASEE Annual Meeting, San Antonio, TX, June 2012.
6. Whitehouse Press Secretary, "Presidents initiative for Advanced Manufacturing", available from <http://www.whitehouse.gov/the-press-office/2011/06/24/president-obama-launches-advanced-manufacturing-partnership>

Appendix A - Manufacturing Engineering Curriculum Comments

- The Four Pillars of Manufacturing Knowledge model should have more wide-spread application and use within manufacturing education.
- Many traditional teaching approaches turn off students. The MIT approach of small clusters of students working on problems with faculty roaming the rooms to explain the problem and providing some insight to self discovery of solutions is one technique necessary to capture attention of Freshmen students.
- Technical education should begin in high school with hands on training in all aspects of machining, welding, electronics, controllers, etc. The focus should be hands on. After high school those with engineering aspirations can take their education to the next level while others are well prepared to move into higher paying skilled labor employment.
- Students need to have the ability to communicate effectively on a professional level, and be able to act/react ethically when they begin their career. A basic understanding of business fundamentals could greatly improve their contribution to an employer as well.
- In order to compete globally, it is necessary for American Industry to reduce costs. A large percent of costs associated with manufacturing are not associated with the processes, but, with how those processes are managed. These problems are not apparent unless the manager/engineer has a systems view of the process. Therefore it is necessary

to teach professionals how to look at whole processes and identify ways to improve the entire system. This will require problem based educational methods.

- Mechatronics
- Your questions seem mostly developed with an aged view of 'Manufacturing' - there are many jobs in biological and chemically-based industries which do not readily fit with this set of questions. Most important future aspects required in an education to equip future ME's include business awareness, communication, project management, teamwork as well as chemistry, physics, logistics and math. with consciousness of the economic and strategic impacts of globalization. Ability to understand, analyze and work with all manner of processes, and with equipment to deliver these processes will be critical.
- General print reading and GD&T skills seem to be really weak among current students from my interaction with them.
- Young design engineers don't seem to understand enough about various manufacturing processes, and even less about Design for Manufacturing and/or Assembly. I see simple break edges with 0.02mm tolerances showing up on prints, and no concept of the differences in six sigma capability between small lot CNC prototypes and medium to high volume production on speedier equipment like a cold header, progressive die stamper, or screw machine.
- Process Focused and Certifications
- Manufacturing Sectors and Processes: Process planning and production deployment fundamentals (regardless of sector), hands-on integration of at least two process/sector types
- Educational Methods: Classroom inversion, course project integration with industry"
- Production systems, lean and quality are top priorities for those in BS programs. Certainly a broad understanding of the basic processes is important, but industry area may be regional in focus.
- Most job openings are currently in Mechatronics and CNC programming. Need to have problems solving skills, work as part of a team, soft skills like being on time, and communicating well.
- Real world experienced educators teaching usable / applicable subjects. Not the typical PHD no real world profs teaching abstract theories or impractical subjects.
- Automation, quality, lean, CAD/CAM, robotics, team work, ethics, projects
- Manufacturing Processes taught by Laboratory projects
- Ability to make well-rounded decisions.
- Ability to use specific decision-making tools.
- Ability to estimate and create budgets.
- Ability to lay out a project schedule.
- Basic project management skills.
- Basic business skills: budgets and P&L statements.
- We need to prepare all people with the fundamental basics which will permit them to develop a professional specialty later and to also function as technically literate citizens.
- basic engineering science of heat transfer; several sensor/instrumentation/computer data acquisition & control courses; senior project
- The topical area is not as important as teaching ways for manufacturing to be competitive. This means working across disciplines.

- Our program is for mechatronics, automation technology, manufacturing robotics, drafting and design technology, and computer programming. We focus on automation technology, but should get into higher levels of mechatronics as well.
- manufacturing processes, automation, sustainability
- Hands on education with labs is a must, CAD CAM Programming, Q&A, Metrology, GD&T Reading and Applying, All are very important topics to teach our Mfg Engineers
- universities are using buggy whip methods to teach current and emerging technologies. They're stuck in the past and will not change. Another big issue is academic politics. Excellent educators who want to bring new ideas along with making students responsible for their behavior are being forced out of academia. It's just a good old boy system lacking any accountability and it does not have a clue about due process or transparency. Bigots, liars, hypocrites, and bullies join forces so they can get away with their unethical behavior.
- Lean manufacturing, Project management
- This is nothing new. I've seen this through my whole career. The "ups and downs" of manufacturing. We need to move to "learning to learn", you educate a person, you train a dog. The modern day student doesn't know which end of a hammer to hold. Modern "education specialist" tells us they are a "digital generation". Yes, they can social network, but other than that they have no clue. "Drill down" with any employer and you will find the real skills needed. Show up to work, willingness to work/learn all of the 1950's skills. How do you change this; adapt the medical model to elevate the profession. I've seen it in Europe, Asia, and with my son in the Marine Corp it works. Stop "wet nursing" and set standards, when is the last time you hear a Nursing Program or Medical School needing recruit the best
- Manufacturing Processes, especially metal cutting (machining) and forming.
- Pair up the teaching of theory with choosing real parts/components so that students learn both "how stuff works" and common practice. Common practice can make students more useful from the very beginning of their careers and knowing theory will advance them beyond graduates with no theoretical background.
- Advanced Processing, Advanced Materials and how to apply materials to optimize part mass, cost, and complexity should be helpful.
- Cost estimation methods should be taught at the graduate studies in manufacturing.
- CAD/CAM, Lecture/laboratory hands-on, Essay
- Mechatronics
- Need more focus on mfg. The USA needs to be able to make products for a healthy economy and growth. Get people back to work; engineers and engineering schools have a social responsibility to do that. Losing mfg in the states perpetuates an innovation brain drain as we lose the ability to build and develop new products.
- Need more quality classes such as design of experiments and problem solving. Integration of software and hardware for production equipment.
- No student at a publicly-funded institution, either K-12 or collegiate, should graduate without a usable, sale-able skill. If they also become an educated citizen as well, that's a plus.
- Breadth of work activities they will face, and must be willing to undertake.
- Students need to develop good all round abilities to provide themselves with wider range of employment opportunities and employers with multi-skilled (flexible) employees. In

general, students are being well prepared academically, are poor at applying these skills in the real world.

- Materials Science, Materials Processing, Face-to-face w/ hands-on laboratories with problem solving and design-build-test activities. Seeing a greater need for graduates to be equipment savvy...the absence of manufacturing in the US coupled with the "social media" culture of our incoming students has created a limited grasp of tools, equipment, processes, etc. related to the manufacturing environment.
- classical IE courses
- Need to continuously evolve topics based on direction of US based manufacturing industry.
- Manufacturing education from a technical content perspective is, for the most part, adequate. More focus could be paid on interdisciplinary project-focused learning as well as hands-on experience through internships or co-op opportunities. Manufacturing students are grossly undereducated on the core drivers of business. Companies locate or re-locate based on a complex set of environmental factors including taxes, labor unions, environmental and other regulatory considerations, etc. Technology is necessary, but not sufficient in helping the U.S. recover its former position in global manufacturing.
- Students need all of the basic education relating to processes (machining, forging, etc., in addition to emerging technologies such as additive processes). They also need education about the key industries such as aerospace, automotive, energy, etc., focusing on what challenges and technologies are unique to each. In addition to this, and perhaps, just as important, is a financial background that provides engineering students with knowledge of how decisions are made within an enterprise, and how design and manufacture are ultimately influenced (or even "driven" by these considerations). It is also important for engineering students to realize that their future success in industry is predicated on their technical knowledgebase and skills, but heavily influenced by their interpersonal skills as well. The success of projects in industry is often based on the ability of the project lead and contributors to work with people from different technical as well as non-technical backgrounds (i.e. engineering, sales, purchasing, marketing, etc.). Exceptional communication skills along with a strong "EQ" are therefore highly needed.
- basic manufacturing methods and techniques need to be started in the middle and high schools in order to assure that: students are prepared to enter a range of careers from technical workers to Engineering design and management these programs will attract more students to 2 and 4 year manufacturing-related programs. such students will be better prepared for university education and more likely to complete their studies.
- co-op was invaluable!
- A core competency across all manufacturing sectors that is missing from your options above is the collection and analysis of manufacturing information and the subsequent actions that result. Manufacturing efficiencies are directly dependent on the proper application of applicable metrics at the various levels of manufacturing management.
- Software development skills will be increasingly important as manufacturing becomes more automated and PC-based controls and user interfaces continue to become more cost effective. This is also true for mobile based application development."
- Too many students coming into industry are not current on lean principles.
- Have not utilized my education by having a Manu. Eng. position

- Topics: product engrg; process engrg; production systems design; product development & realization; innovation
- Methods: discovery/inquiry learning; project-based
- Graduate Skills: design of products, processes & production systems; universal manufacturing principles
- topics taught: product and tool design, manufacturing processes, materials for manufacturing, quality engineering, systems engineering, value engineering
- teaching methods: lectures, labs, project based, case studies, problem solving
- graduate skills and knowledge: doctorate in materials engineering, 10 years manufacturing experience, three years consulting experience, professional engineering license
- Business processes for the product producing enterprise
- manufacturing engineering should be among the respected classical disciplines of engineering offering ABET accredited degrees at the BS and MS levels in top universities in the US along with mechanical, electrical, civil etc engineering.
- We should also support technology degrees and certificate programs.
- manufacturing engineering should be among the respected classical disciplines of engineering offering ABET accredited degrees at the BS and MS levels in top universities in the US along with mechanical, electrical, civil etc engineering.
- We should also support technology degrees and certificate programs.
- Manufacturing is the transformation of ideas into useful products and should be approached as the broad range of all transformative processes. New students will be using non-traditional methods and should have a world of digital design and operations as a basis of their education - i.e. Fab Labs similar to MIT “how to build almost anything”
- input from industry on strengths and weaknesses of graduates hired should be used to guide curriculum development.
- early integration of projects, problem solving exercises/practice
- teaching methods need to integrate techniques and technology that reflect learning needs and evolving learning styles of students including online learning of fundamentals, collaborative learning and community building.
- Need more focus on global manufacturing networks, risk identification/mitigation, system design, system assessment
- Students that do not know Pro/Engineer upon graduation will be at a disadvantage in the job market. Both Hope College Engineering and Ferris State have and use Pro/Engineer as part of the program.
- Any method or process that transforms raw materials into value added products or finished goods needs to be the focus. All those listed are important. Each industry will select their own biased reply. Engineering can capture ideas, employ the laws of science and create designs for potential products, but the physical transformation of models, drawings, etc. require trained professionals that can translate that information into physical goods.
- Return on Investment for capital equipment.
- Co-op/ internships should be required curriculum for undergrad engineers. The percentage of new graduate engineers that we hire w/o co-op experience is less than 10%.
- Create curricula that awards a BS degree in only 3 years like that done in Europe. 3+2 and 2+2 transfer programs should also be a top priority.

- The MfE of tomorrow will need to know about both the mass and lean Mfg systems and be able to use the tools for design, analysis and control of these systems. As more and more companies convert to lean, the MfE will have get input and need great people skills to execute the conversions. This will be the job of the lean engineer or the lean MfE and this be the thrust of the SMfE - to educate the MfE of future, to build MfE undergrad and grad programs to help American remain strong in Mfg.
- There needs to be more of an emphasis on the details when working on a project. It seems as though those are often overlooked.
- Do not forget about the basics... Drafting (being able to create working drawings that are manufactureable) Fundamentals of machine (mechanical) design
- All skills in a global, thus virtual environment need to have priority
- As predicting the future of manufacturing can be difficult (if not impossible), a well rounded education with emphasis on how to learn new topics independently as well as functioning in a team environment would be of highest priority in my opinion. The ability (and willingness) to adapt to any assignment and find a way to solve the problem is of highest priority when we are interviewing new candidates.
- This whole survey is poorly conceived... there are too many subjects to make an educated opinion. The future needs less of everything including less manufacturing. The earth is already over-extended. How to use less materials and natural resources is the most desirable approach... and to stop waste and excess. Sharing of big-ticket items also makes best sense, instead of everyone owning and going in hock to have every little and big thing in their garage. All future education should be geared to make our students conscious of the environment and to live and love to live with less.
- Applications!

Appendix B – Industry Interaction Comments

- Educational institutions should enhance their collaboration with industry on curriculum design and on applied research projects.
- Industry has to be a part of the education process. I think the German system would work well in the US. Internships in high school seems to work well in some cities.
- strengthen and expand internship programs,
- Adapting engineering processes to new environments
- Apprenticeships, internships and co-ops must return and students must receive fair remuneration that matches the currently excessive tuition rates. Students must be adequately compensated so that they may enter the workforce almost debt-free.
- Global Collaboration for Product Life Cycle Management
- Integrative project activities WITHIN the curriculum, as a priority at the undergraduate level, as a secondary at the graduate level
- Whenever possible, practical application is critical. The most effective method is use of co-op and internships, but even projects and independent study should be coordinated with industry and be problem-solving based rather than primarily accomplished in a campus laboratory.
- Need more internships.
- More interface between class room and real world.. lectures in class rooms or facility

- tours. Build a bridge between educators and real world.
- Co-Op, field trips, help procuring equipment.
 - Many retiring manufacturing employees. No one to take their places
 - Co-op program is very good.
 - Industry needs to stop trying to have it both ways, i.e., to have high technical competency and knowledge without proper reward to the employee through appropriate level salary and benefits.
 - I see automation as a huge direction for manufacturing
 - Industry needs to learn how to do mfg research. Education needs to learn how to get things done quicker.
 - Industry has directed what qualifications they need from our graduates so our program is directed to that area. I believe that industry will need graduates that can innovate more in the manufacturing process and the product design.
 - NEEed more guidance for topics to teach inform the PhD what is really pertinent in industry.
 - Look to the Germans for a model as they have it down pat.
 - Industry needs to be seriously involved in funding manufacturing education; otherwise, it will be a thing of the past.
 - Be willing to pay for what you get. Every educational institution I know of has advisory committees etc. Again, everyone know the situation, work with companies to grow there own. True partnership works both ways, if they won't send employees to the college program, then what is the value?
 - I'm out of touch with this having retired a decade ago.
 - Our society is clearly shoving skilled trades aside. More and more skilled labor jobs go unfilled. Industry will have to find a way to compensate for this societal mistake.
 - For the automotive industry, Low cost and Low Mass, Highly Engineering technical solutions. Application of advanced processing and materials to optimize above.
 - Internship/Coop/Service learning
 - Internships, Cooperative research, Cooperative projects in lean, safety, quality control, training, etc.
 - Need good co-op programs - students returning for more than one semester
 - Industry needs the skills to be competitive, and needs to step up to the plate and not only demand them of our schools, but be there as a working partner in the educational process.
 - Use of guest speakers to let students what they face when they join industry - it helps open their eyes on the challenges they have ahead.
 - Colleges need to communicate with industries and understand where new employees and resent grads are not as strong.
 - Need industry partnerships to facilitate the improvement of student knowledge and skill base of manufacturing and production. Co-ops and internships. Opportunities for faculty to have short professional development "internships" at production facilities. State-of-the-art equipment placement in academic settings (short to long term loan) for faculty mentored undergraduate and graduate research and also for teaching opportunities to help students who are potential employees of these industrial partners. (as we know, funding for equipment purchases is very limited due to massive budget cuts in education)
 - Local industry has a great need for tradespersons (machinists). As a community college, we are working with them.

- Increased collaboration with industry required to insure needs are being met.
- Companies locate or re-locate based on a complex set of environmental factors including taxes, labor unions, environmental and other regulatory considerations, etc. Technology is necessary, but not sufficient in helping the U.S. recover its former position in global manufacturing. Globally, manufacturing has shifted to business friendly environments. Nationally, manufacturing is in the process of mass exodus from business hostile states to business friendly states, for the same reasons. We should identify policies and practices in Texas, Georgia, and other states that are currently ADDING manufacturing jobs, and push to encourage those policies at a national level.
- Industry tends to shy away from involvement in educational policy issues. SME and other groups need to work to change this.
- Future trends: waste recovery. Landfill space is getting tighter. Also, resource recovery from landfills. Water/wastewater industry.
- Industries will need to continue to utilize technology and process improvement tools (Lean, Six Sigma...) to ensure that they can deliver a superior product at a competitive price.
- Manufacturing in America will not get jobs back from China unless we can be more competitive.
- Contributions: mostly confined to narrow self-interests, especially to fill last year's needs
- Needs: people with fundamental knowledge, willing & able to learn & adapt to new job requirements; innovative mind-set
- Trends: accelerating needs for product and process innovation
- more industry interaction is needed, sponsorships, capstone projects, internships, academic advisory boards and so on.
- Much stronger ties to industry and student projects and support for internships for undergraduates
- Industry/ engineering education cooperation is essential. Industry with government's support should offer paid internships, coops and full ride scholarships to Manufacturing engineering students
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- I have MBA and MSEE degrees, am a recently licensed Professional Engineer, am a certified Project Management Professional (PMP) and Six Sigma Black Belt. As an independent consultant, and as an aging professional, I have found each of these necessary at various times. The Black Belt was once hot but seems to have fallen somewhat in its' desirability. PMP certification now seems to be the hot commodity.
- We need to have more involvement if industry with students, Cooperative learning opportunities for all should be required in all technical course areas.
- industry should be called upon to define depth of learning on topics needed, provide projects, internships, coop opportunities, career development, etc.
- Industry-university interaction is a two-way street, both have to be engaged. In current economic & political environment, not clear this is going to happen. Both have been driven to be "lean" and to "focus on core mission" so neither has resources to deploy for interaction.
- Processing of agricultural based commodities has been neglected with primary focus on

rust belt technologies.

- An agricultural success story is AgroFarma and its product called Chobani greek yogurt. Other commodities such as meat, grains, dairy and biofuels need similar re-invention.
- Industry needs to make sure that there is support for undergrad internships and cooperative education programs.
- More connection with industry through professional development certificates for those already in industry and a huge expansion of co-op programs. Industry gets the benefit of universities preparing their workers, but should be far more engaged in that process through internships and co-op programs.
- Slowly but surely, Industry is leaning that it was a mistake to ship out so much mfg to the rest of the world. and it will be soon be coming back to America.
- We need more collaboration between different industries to help brainstorm and get new ideas. Grid 70 is a great example of companies that have come together to brainstorm in one building.
- More Justin Bieber!
- The more interaction the students get to industry the better. They need hands on experience on their resume by the time they graduate to prepare them for their first full time job.
- Efficiency, best practices, innovation, creativity, sustainability, entrepreneurship,in other words, just try thinks out even you fail once, twice or three times in a row. Do not give up!
- Right now I see Agriculture as being a growing industry. There is need for good engineers with equipment design, and manufacturing experience as well as a need for structural engineers and anyone with Construction experience.
- Focus should be more industrial in nature. focus on systems to integrate production processes better and take out inefficiencies and improve productivity.
- professional experience

Appendix C - Other Comments

- Educators should be spokespersons for the importance of manufacturing in the U.S. and globally.
- Hands on Certification
- The top competency gap areas seem to still apply, although notable progress has been seen across many programs. Teamwork, project management, economic justification, technical communications remain important across a broad array of organizations and continue to be noted by advisory committee/board members.
- Professional development seems to also be highly regarded for new hires, particularly technical organization leadership, professional certifications, and knowledge of concepts such as Lean, Quality, Six-Sigma, Theory of Constraints, and other topic areas that remain widely in development and deployment by hiring organizations.
- I am an electrical engineering technology faculty, so my replies are skewed to that sector of manufacturing.
- I tend to lump electronics, alternative energy, and nanotechnology into the same

- category, so I chose something different for the second educational priority"
- Global travel and ability to interface effectively with a diverse team is a critical skill-set in my work - and likely for many other engineers.
 - Manufacturing is one of the few ways to increase wealth. Service industries and jobs do not increase wealth.
 - Manufacturing requires significant knowledge not only in the technical fields but also in non-technical fields.
 - Stop referring to important and essential non-technical skills as "soft skills". This is arrogant and does not recruit the help needed to teach present and future employees these skills.
 - Sustainable manufacturing should be the top priority,
 - The most significant trends affecting industry and education in the future:
 - Sustainable development (low-carbon economy, sustainable growth, renewable energy, etc.)
 - Healthcare and the aging population. This will drive the need for advances in biomedical engineering, among other areas.
 - I have noted "liberal education" as a priority as I feel students lack an awareness of the bigger issues. This would include related studies in political science, social science, geography, etc. with a theme of sustainability and other important issues.
 - I selected design as a priority. I prefer to think of design of socio-technical systems as opposed to discrete products.
 - I retired from industry nearly 6 years ago. My opinion is that a strong manufacturing base is essential to national economic strength, and I believe manufacturers can be competitive in the global market place through improved manufacturing/production methods.
 - The US is getting further & further behind in innovation and manufacturing skills. Instead of focusing on the profit margin for the next quarter business & industry needs to learn real strategic thinking/planning. Just one year or even five years in advance is not sufficient.
 - The short-term profit MBA-driven industry mentality has to be trashed in favor of a longer horizon.
 - Writing skills are still very much underplayed in college, but have major impacts on success rates in industry.
 - Our industrial advisory board is telling us that our Mechanical Engineering curriculum must include, even though it is not traditional engineering science, green/sustainability content and also integrate lean manufacturing and other "world class" manufacturing content into the curriculum in order for student knowledge of manufacturing operations to be compatible with the competitive global market. (Traditionally, these topics have been more related to industrial technology and industrial engineering)
 - Trades training is in great demand. A very visible connection between trades, technical work engineering and science is needed.
 - My current role is business development for industry-sponsored R&D. Key topics for me professionally are understanding the tax and policy practices of competing regions to better understand the competitive landscape, and to identify and utilize differences to the advantage of my state & employer. Engineering students in general leave college well trained technically with little to no exposure to business, economics, or policy - the items that ultimately define whether industry is successful.

- More hands-on is always needed in education.
- I work as a manager for a transportation company. We do unload trailers full of products. Most are made in China. Until that changes the manufacturing sector in America will not grow significantly. Thank you!
- More than ever, “manufacturing” requires breadth of knowledge and ability to apply it. Topical emphasis should be placed on widely applicable principles of manufacturing, with project work that applies those principles to the industries most relevant to the particular educational program.
- Laboratory study remains crucial - learning something about what happens when the tool meets the work piece. We are not supposed to be training machine operators, but we surely want our graduates to be smarter than the computer programs that they use.
- Metrology (and measurement technology, in general) is an under-emphasized topic - and is one of the universal tools applicable to any and all kinds of manufacturing.
- Fundamentals are still important. The five pillars of manufacturing provide an outstanding guide for program assessment and continuous improvement. The traditional metal removal processes must be supplemented with other new and non-traditional processes.
- Biggest problem in Manufacturing education is the defensive strategies implemented by classical engineering disciplines especially mechanical engineering discipline proponents. Current ME education curricula favor thermal sciences with token offering of elective mfg related content. Shop operations and lab work based on actual design and production of original products must be supported
- Biggest problem in Manufacturing education is the defensive strategies implemented by classical engineering disciplines especially mechanical engineering discipline proponents. Current ME education curricula favor thermal sciences with token offering of elective mfg related content. Shop operations and lab work based on actual design and production of original products must be supported
- In the next few years most states may require an Engineering Master Degree to test for the Professional Engineering (PE) license. As a minimum they may require continuing education. There are a number of BSEE, BSME, BSCE engineers that are not aware of this coming requirement. Schools of engineering should not be surprised at the number of Master applicants they will receive once this requirement is in place.
- An older reference from 2010:
http://www.todaysengineer.org/2010/Jun/PE_Requirements.asp
- Graduate should acquire problem solving skill in addition to technical knowledge.
- Students graduating today are not well informed about manufacturing processes. Casting, forging, machining, laser and water jet cutting, precision grinding, molding, heat treating, etc. all need to be witnessed and discussed to prepare a new team member to contribute to creating value. They don't need 8 classes but they need to get out and see the operations in person.
- Good writing skills are also required. Many undergraduates need the honing of this skill to be successful. More project reports, reviews of practices, etc. would benefit.
- Software development should be a category of study topics above.
- Green manufacturing and new methods of recycling should be a top priority. There is also a need for more international internships and co-op programs so students are more exposed to how things are done in a global marketplace.

- Almost all of the stuff coming out of SME ignores what should be their key mission. They are the Society of Manufacturing Engineers --not the Society of Manufacturing. They are the only society that can raise the status of the MfE to where they can compete with MEs, IEs and other engineers.
- Passion is important to have wherever you end up working. If you don't have passion work will always be tough.
- More knitting and basket weaving!
- Study Topic - Second Priority = Machine Design
- all the topics are important. Hard to make a decision on priorities with the first 2 questions.