AC 2011-144: EDUCATING MANUFACTURING LEADERS: CREATING AN INDUSTRIAL CULTURE FOR A SUSTAINABLE FUTURE

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Educating Manufacturing Leaders: Creating an Industrial Culture for a Sustainable Future

Abstract

Manufacturing is about processes, materials, systems and competitive strategy. It is also about people, how they perform and how they are led. Most research on manufacturing has been conducted on processes, materials and systems. The time has come to devote more attention to people and competitive strategy. With the persistent, chronic public perception of manufacturing as a smoky, dirty, dimly lighted 19th Century factory, we need to highlight and emphasize the positive, societal benefits that manufacturing brings in order to attract more young talent to manufacturing and bring more manufacturing back to the US. A new kind of leadership is needed. This paper discusses a course in leadership development in a graduate manufacturing program for working adults. It contains results based on interviews with alumni that demonstrate the power of this process and the new competitive capabilities enjoyed by the companies at which these alumni are employed.

The Future of Manufacturing

The United States needs a strong manufacturing sector to face the challenges of this Century. The strength of the manufacturing sector is the supply chain of smaller manufacturers. While some manufacturing companies are very advanced and innovative, they tend to be the larger organizations. We need more small and medium sized manufacturers to be innovative. Why? So they can take a larger role of greater value in the supply chain, keep pace with and support the most innovative organizations, become more competitive and ultimately more sustainable as an economic contributor.

Manufacturing is not just the traditional machining of steel of the 19th Century. Advances in new materials and processes make manufacturing much more complex and much more exciting. Small manufacturers need to invest in R&D, in training, and in modern leadership who will create organizational cultures that provide incentives for innovation. We need incentives to help these companies to collaborate and build teams with skills to meet the daunting challenges we face today, and which will become even more challenging in the future.

Small companies are often private firms. They enjoy a major advantage in that they are flexible and responsive. They are not being driven by short-term thinking and erratic valuation of their stock, as are many of the larger firms. These companies can make decisions that are in their best long-term interest, and the best long-term interests of the economy. They need to capitalize on this advantage to revitalize the strength of the manufacturing sector in the US and take charge of our economy.

In addition, public relations for manufacturing need updating. To do this, manufacturing leadership in organizations large and small must make the image, and the reality, of manufacturing in the United States more visible. They must be more active in their communities, creating awareness of the value that manufacturing brings to the economy.

Manufacturing factories are viewed by the public as 'black boxes' with hidden contents. Manufacturers must open their doors to the public, especially to students, to show how manufacturing has changed and demolish outdated perceptions. This will take leadership.

Manufacturers need help in developing leadership. There are many opportunities, but it takes initiative to make the connections needed. Manufacturers need to reach out to post-secondary institutions in their communities. Post-secondary educational programs are ready to partner with manufacturers in providing education, training and on-site programs beyond production methods that include content covering leadership. They can help leaders develop the characteristics needed to create the environment for the employees to become more innovative and see their role in the larger systems context. This has been the objective of the Society of Manufacturing Engineers and the program specific curriculum criteria they have established for Engineering Accreditation Commission (EAC) of ABET accredited manufacturing engineering programs.[1]

ABET Manufacturing Criteria

The Engineering Accreditation Commission (EAC) of ABET program criteria for manufacturing[1] requires that programs demonstrate that graduates have proficiencies in five specific areas: 1) materials and manufacturing processes, 2) process, assembly and product engineering, 3) manufacturing systems design, 4) laboratory experience, and 5) manufacturing competitiveness. Manufacturing competitiveness requires understanding the creation of competitive advantage through manufacturing planning, strategy and control. While the first four requirements are primarily about things, the competitiveness requirement is all about people. To fulfill this requirement, students need to understand and exercise leadership. We manage things, but we lead people.

Manufacturing planning, strategy and control are elements of management, but leadership goes far beyond this. Thinking of these requirements in terms of just management is of another era; as an old saying goes, it is '*mistaking the edge of the rut for the horizon'*. These requirements must be viewed in the context of leadership that fits the needs of the 21st Century. The complexities of planning and developing strategy in a global economic manufacturing environment have become much more difficult than in the last century. The approach to leadership for this environment must keep pace. Internally, leadership must draw on all the skills of every employee to develop the innovative processes and products that meet the challenges of global competitors. Externally, these leaders must change the face of manufacturing to the public, showing the tremendous impact of manufacturing on our quality of life[2], and making a career in manufacturing an attractive option for students. These leaders must also make the case to the general public and to public servants for strengthening manufacturing at home. In addition to the short term requirements of increasing the attractiveness and competitiveness of manufacturing in the United States, these leaders must keep an eye to the future and develop sustainable processes and products that consider the long-term effects of their decisions.

Value Creation Model

How can this be done? An instructive diagram that helps us understand this process is provided by the Value Creation Model (Figure 1) developed by Arnie Weimerskirch and others at

Honeywell[3]. Exciting products that generate repeat business, and lean operations that reduce waste and cost, are all created by innovative employees working in a supportive environment created by management.

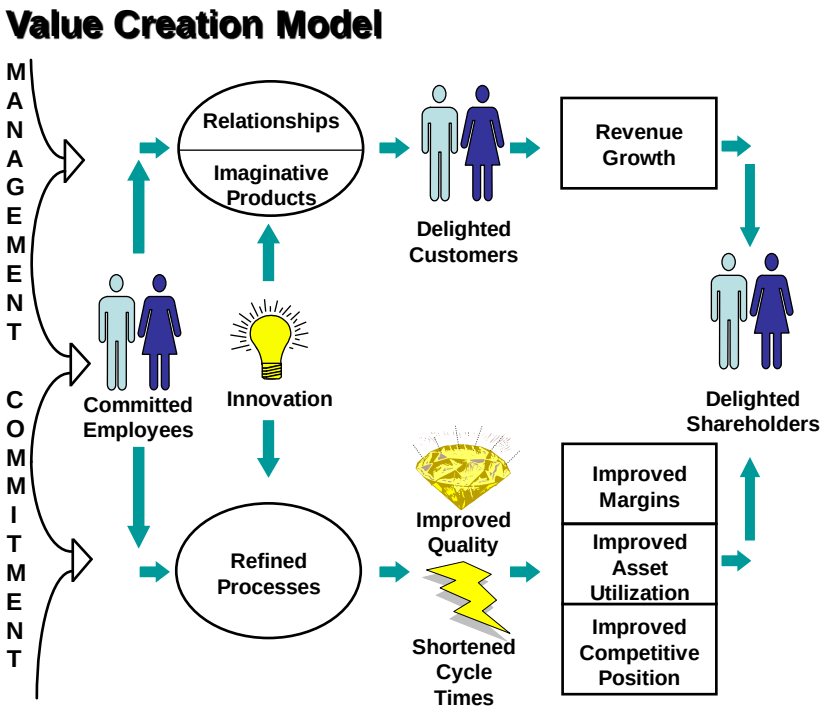

Figure 1. Value Creation Model

Interviews with alumni of the graduate programs in manufacturing at the University of St. Thomas have illustrated how this not only *can* be done, but how it *is being* done. Several of those cases will be cited later. The key point here is that leadership is needed at all levels, and programs in manufacturing education need to make the development of leadership skills and attitudes of their graduates a priority.

Changing the Perception of Manufacturing

Manufacturing engineers and manufacturers in general seem always to be on the defensive. There are frequent stories about the negative 19th Century image of manufacturing, how it is difficult to attract young people into manufacturing, and how it is difficult to get parents to encourage their children to go into manufacturing. In an article published in Measures of Success[2], a case was made that the high standard of living that millions experience, previously reserved for kings and the richest few, would not exist were it not for manufacturing. In the article, we discussed the key role that manufacturing has played in increasing the quality of life. People today live better than the kings of past centuries, due largely to the ability of manufacturers to produce quality products and services that are affordable to large numbers of people.

To reinforce the importance of manufacturing in the United States, the Presidents of Harvard and MIT have recently come out in support of strengthening manufacturing in the United States[4]. Said MIT president Susan Hockfield, "if manufacturing is old-fashioned, then we're not doing it right." It's time to change that negative image, and it's time to change manufacturing.

Manufacturing engineers need to raise the perception of their profession as being a major contributor to our standard of living. Without cost reductions created by manufacturing engineers, we wouldn't be able to produce and buy all the great things that improve people's lives. The abundance of affordable products, once considered the luxuries of the elite if they were available at all, are the result of a strong manufacturing sector. Such products as food, medical products and procedures, communications, entertainment, transportation - the list goes on forever - would not be commonplace were it not for a strong domestic manufacturing sector. Manufacturing engineers have the skills to produce very cost effective products. In manufacturing organizations of all sizes, they must now add the skills and attitudes of leadership to plan, strategize and control their internal operations and supply chains, and to lead the initiatives to re-establish public perception of the importance of a strong manufacturing sector to our economy.

The 'Circle T'® Shaped Engineer

Some authors have referred to the need for the 'T' shaped engineer. The notion is that the vertical stem in the 'T' is technical depth, and the horizontal bar is systems breadth. We are expanding this to the 'Circle T'® shaped engineer, with the 'Circle' representing the larger context that is leadership. To be an effective leader requires technical depth and the broader education that enables engineers to understand the systems in which their technology operates. These are necessary, but not sufficient, conditions. It also requires an understanding of systems and relationships for manufacturing engineers to be really effective leaders. The EAC of ABET program criteria for manufacturing programs call for just that; "*the understanding and creation of competitive advantage through manufacturing planning, strategy and control*". The leadership skills needed to serve that criteria are those of the 'Circle T'® shaped engineer who has a broad education that enables her/him to have a vision, see the manufacturing operations in a systems context, and to take the initiative to create change.

The Bicycle Model

One can think of the engineers and manufacturers role as a leader in terms of a bicycle[5] (Figure 2). The technical skills are represented by the rear wheel and the power train. These skills give the leader a strong basis in understanding the nuts and bolts of what needs to be done. The front wheel, representing the leadership skills and systems knowledge, allows the leader to steer her/his technical skills in the desired direction.

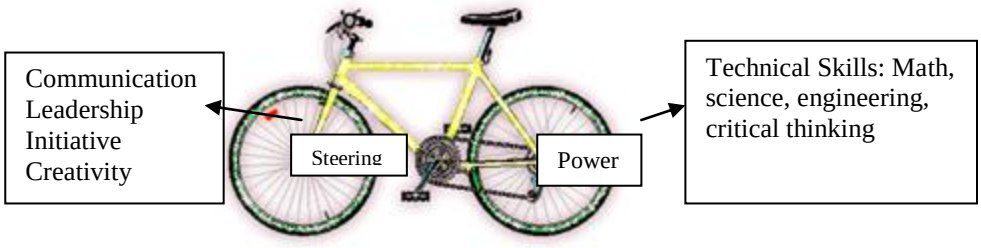

Figure 2. Bicycle Model of leadership

Without steering, this power will take the engineer in no particular direction. She/he needs a front wheel to control her/his direction. The front wheels are the right brain elements like reflection, leadership, communication, courage, initiative, creativity and innovation. These capabilities make the engineers 'bicycle' complete and will keep him/her on the right path. During the development of the engineers technical capabilities, the skills needed for his/her front wheel may have been neglected. That can be fixed through appropriate leadership learning opportunities.

Sustainability

Many engineering programs have students participate in the Order of The Engineer ceremony. This ceremony arose from the failure of a Canadian bridge as a result of poor engineering, and is meant to emphasize to the graduates the importance of their work in providing for the safety of the public. The Obligation of the Engineer[6] states that engineers have three responsibilities: to act fairly, to conserve nature's resources and to serve the public good. Conserving nature's resources of materials and energy is at the center of what manufacturing engineers do, since a central theme of manufacturing engineering is to take cost out of products and processes. This is done by identifying the most appropriate and cost-efficient materials that will satisfy the design requirements, and to make processes lean to reduce their cost. Both of these requirements make it incumbent on the manufacturing engineer to lead in considering and evaluating alternative materials and processes for any given application, and for manufacturing leadership to create the culture that fosters innovation and a positive change in the perception of manufacturing.

The manufacturing engineer has an additional obligation, and that is to help design products that are compelling to customers, products that customers want to buy, and products that they want to continue to buy. This requires that the manufacturing engineer become much more engaged with marketing, design engineering and customers to aid in the creation of these products. All of these requirements are contained in the Value Creation Model previously described.

Summary of 2004 Paper on Leadership Development

At the ASEE annual conference in 2004, a paper titled "*Beyond Professionalism to Leadership: Leveraging Leadership for a Lifetime"* was presented by the authors on the motivation for a course that helped working adult graduate students assess their leadership capacity and skills, discussed the nature of the course and reported the results observed at that time.[7]

The idea for this course series began in 2000 when our Industry Advisory Board was reviewing the program objectives and mission. This discussion ranged into the definition of leadership and professionalism. At the same time we began a benchmarking initiative of six other university engineering schools, searching for best practices. These benchmarking visits and advisory board discussions provided ideas that we incorporated into our plan for a new approach to assessing the effectiveness of our masters programs.

After considerable discussion engaging many stakeholders, we created a new three-part course titled "Leveraging Leadership for a Lifetime" (LLL-I, II, III). Course details can be found on the University of St. Thomas School of Engineering website.[8] This sequence of three one-credit courses, spread throughout all masters degree programs, was designed to provide the student with an ongoing close look at herself/himself as a learner, a leader, and the person in charge of her/his life-long plan. The series intended to answer the question, "How do I get the best possible results for my life goals from this graduate program?"

With faculty and industry engagement, we identified specific learning outcomes for the leadership series, critical features for the process and expected outcomes for each of the courses. We used a set of critical design assumptions as our guide for development. These assumptions were based on adult learning theory as well as motivational theory. Furthermore, we felt the students should take personal responsibility to be actively involved in their learning agenda, shape a vision for their leadership and learning that would guide their planning process while they deliberately focused on increasing their self-awareness and understanding of a leader's social/ethical responsibilities.

The three-course series began with a thorough base-line assessment of the individual graduate student's competencies, personal values, learning style, leadership aptitude and other data (both qualitative and quantitative) regarding their personality profile and emotional intelligence. Each of these areas was seen as a critical ingredient contributing to the leadership capacity building process. Students used the data as a foundational building block in designing their roadmap for learning and leading.

The key to understanding and developing one's leadership abilities lies in understanding ones beliefs. It requires looking inside to find your inner leader. This has been with working adults in the graduate programs at the University of St. Thomas School of Engineering, including those in the Master of Manufacturing Systems Engineering and the Master of Science in Manufacturing Systems programs.

At the time of the initial survey documented in the 2004 paper, students were excited about their learning pursuits, engaging others to support them and beginning to demonstrate their leadership talents as they learned, stretched and grew. They were feeling real strength and power in coming to better understand themselves and taking charge of their own learning outcomes. With an additional six years experience, the power of this approach in *releasing the leaders within* is becoming much more clear and compelling. Alumni of this program are now convinced that this course has had a profound effect on the way they view the world as an interconnected system, on their role to lead and make a difference, and as a result has changed the way they think.

Alumni Interviews

Many of our alumni, particularly from the Master of Manufacturing Systems Engineering program and the Master of Science in Manufacturing Systems program, were traditional manufacturing people when they entered the graduate program. As they learned about the importance of people in the manufacturing organization, they have grown into leaders who are changing the way manufacturing is viewed. Several examples stand out. [Note: interviews were done under a research project covered by the University of St. Thomas Institutional Review Board. In accordance with the agreement, anonymity has been maintained by using pseudonyms for alumni. The industries represented and stories are factual.]

As a student in our Master of Manufacturing Systems Engineering program, Alumnus Nate Keyes was then an engineer at a company that manufactured ammunition. He is now President of a company that manufactures high end machine tools and is changing the culture.

> Nate was hired as the vice president of manufacturing at a company that manufactures high-end tooling. As good as this company was, there was work to be done, and his personal leadership skills would be tested. He recalls first meeting the manufacturing manager and asking, 'how's your quality?' The answer, 'It's so good we don't measure it.' So now what? Nate suggested to the manager that he get some orange buckets and place them around the plant. If by chance there should be some defect, the part could be put in the bucket. When the bucket became full, they would place it in the front entrance for all employees to see. It didn't take long to fill one bucket, then two, then many. One of the seasoned manufacturing people soon stopped by Nate's office and said, 'Nate, I think you're onto something.' He helped the employees discover the problem for themselves and created an environment for them to solve it. While Nate had position power, it was his personal power and individual leadership that made the difference.

Nate has made his company a model of modern manufacturing by viewing the organization as a collection of people who are empowered to be innovative. Another example is that of Hank Bolles who learned how to lead a culture change.

> Hank began his career as a manufacturing engineer in a company that produces fluid handling equipment. In the early 1990s, Hank was assigned to a lead team that was transforming their production from a factory functional structure to a cellular, focused factory. This transformation was cutting-edge at the time and game-changing for the company. Not only were they transforming to cellular manufacturing, they had to keep production going in two plants while they were moving equipment. This experience showed Hank what he could do. Also, being on the lead team was highly visible, up to the CEO. He got to know the leadership of the company personally. He learned how they thought. During the transformation he gave numerous presentations to other employees, explaining why the change was important and why it made sense. He learned about change management, used the company newspaper to communicate, and explained what was happening. In one presentation he used a graphic showing old vs. new product flow – going from a 'spaghetti diagram' with miles of product travel to the simple and elegant flow of cellular. It made the point. The experience proved to Hank he could make change happen, he learned how to

effectively speak before groups, and he learned how to communicate to all levels in the organization. He did this all from the position of an engineer. It gave Hank visibility and confidence that has led to new opportunities he never imagined.

Nate and Hank have continued to plan the futures of their organizations manufacturing operations, have developed and implemented strategies to carry out those plans, and have established controls to keep their organizations on course. They have done this in the format of the Value Creation Model, engaging everyone in their organizations to be active participants, tapping into the energy and creativity of every employee. Dan Jansen had similar experiences of taking on a leadership role. In his case, he had no position power, only personal power, and yet accomplished exceptional results.

Dan recalls his first significant leadership role in industry. He was a manufacturing engineer in an aerospace engineering company. A major aircraft project on which he was working was experiencing cost and schedule overruns. With that project completed, he was assigned to another project on the next generation product. Dan gathered some of his engineering colleagues together and, using learning from past experiences and from our graduate manufacturing program, he proposed changing the way they did this project. He recommended point of use stores near production, pull vs. push methods, and disposition of nonconforming product on the spot and other modern manufacturing thinking and methods new at the time. He didn't ask permission to do this, he just did it. It was the right thing to do. He taught the approach to those not familiar with these methods and because he had thought them out well, his colleagues saw the merits and joined him. It just made sense. Members of the group saw the benefits from their own perspective. They made sweeping changes that took management aback. The result was dramatic improvement: it took 180 days to get the first components manufactured; by the end of year one, they were producing one unit per day. He did this all without official sanction. The other engineers worked with him to develop a vastly improved process that resulted in on-budget and on-schedule performance. Dan was not asked to do this: he took the initiative to take charge, for the benefit of his company and of their customer.

Individual initiative based on 'doing the right thing' and on understanding what motivates people is a theme that emerged again and again in these interviews. Ellie Fitzgerald and Bobby Bridges are two more examples of heads-up initiative.

As the leader of a small team in a medical device company, Ellie was confronted with a situation where four team members each had different points of view on how to handle a specific situation. Ellie set up a two hour meeting and stood at the board, laying out the pros and cons to each approach by asking the team questions and documenting their responses. Doing this exercise systematically helped all the team members realize the appropriate path, and all she did was facilitate their discussion in a productive manner. The team agreed on one approach and all left the room win-win.

Bobby was an engineering manager at a truck assembly plant. For many years, the corporate quality group had tried to establish a top-down process to monitor and correct cab welding problems, but it never caught on. Bobby had developed a process to do this in his plant. Every weld could be traced to a specific machine and tool, so defects could be detected and

corrected quickly. He shared this with his colleagues in other plants, and word spread. It was readily accepted, and is now the corporate standard. Bobby had unassumingly shared the methods he developed, and was recognized corporate wide as the leader of this initiative.

There are many more examples, but these five show how real manufacturing people are innovating and creating cultures for sustainability. They are changing the perception of manufacturing in their own organizations. They are creating value and making their organizations more globally competitive. These are individuals that are fully developing the horizontal part of their 'Circle T'® and steering their technical power in the direction of manufacturing competitiveness.

Survey of Engineering Deans

During the past year the authors have conducted surveys of engineering school deans[9] to determine their views on the need for leadership education for engineers, and on their current capacity to deliver this kind of education. While just 46% of the schools responding said they offered leadership education for their undergraduate students and 21% to their graduate students, fully 100% felt leadership education for engineers was important.

Research over the past several years has provided evidence of the success of the approach taken in the School of Engineering at the University of St. Thomas. This model demonstrates a proven process for delivering graduate leadership education to engineers and can be expanded to other adult practicing engineers to become leaders.

Despite the survey responses regarding the perception of importance of leadership skills for engineers, many programs find it difficult to incorporate into their curricula as a separate course because of the demands of other curricular elements. There is a clear need to find alternative ways for these programs to provide leadership education.

The components of the leadership development curricula at the University of St. Thomas could be integrated into other courses in the manufacturing engineering curriculum and even into extracurricular activities like SME Student Chapter programs. Any course that is used to meet the EAC of ABET manufacturing specific curriculum program criteria would be a good candidate. Work is ongoing by the authors to assist programs who want to use this approach, including documentation of the process in a handbook[5].

What's needed in Manufacturing Engineering Programs

Manufacturing engineering programs need to build on the manufacturing competitiveness criteria. There is a strong need for manufacturing planning, strategy and control. This requires change, and the strong leadership needed to make change happen. The global economy has thrown old assumptions out the door, and today's manufacturers need to have leadership to bring manufacturing and jobs back to the United States. This is being done in some places already, and we can spread it to others.

This will require changes in these programs. Many will interpret this as a need to 'add more courses', but this is the linear left-brain approach. We need to be more creative as faculty to first better understand leadership and find ways to integrate leadership education into our programs. It does not require a new or stand-alone class; we can integrate leadership into existing courses and extracurricular activities. While we strive to develop courage, creativity and competence in our students, we need to do the same in our faculty.

Faculty interested in pursuing ways to introduce leadership into their curricula can use the model developed at the University of St. Thomas as a start. Detailed syllabi for the Leveraging Leadership for a Lifetime (LLL) courses are readily available on the website.[8] Using this same approach may not work for all programs. We suggest using the elements included in the LLL classes and adapt them to your environment. You may decide to put segments into existing classes, or partner with your university counseling office to administer assessment instruments, or build some of these ideas into student chapters of SME. It is the leadership concepts that are important, not the specific way you decide to implement the learning.

What can practicing manufacturing engineers do?

Practicing manufacturing engineers can play a major role. They can identify the opportunities and needs in their organizations to enhance their competitiveness, create value in their organizations and become more sustainable. They can seek out and partner with their local educational institutions to identify how these programs can enhance their learning outcomes and deliver the program objectives that manufacturers want and need. They can work with nearby post-secondary institutions to bring leadership education into their companies. In practicing their own leadership development, each manufacturing engineer can seek to find their inner leader, and build conscious competence, confidence and courage. Each person, in their own unique way, can make a difference.

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