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Mass Customization and Its Curricular Implications for Four-Year Degree Programs in Manufacturing Technologies

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Abstract

Mass customization is fast emerging as a popular business strategy which aims to also cater to individual expressed needs of end users at prices closely comparable to mass produced items. Companies are able to switch to this mode of operation by primarily making their own operations demand-driven, flexible systems and asking their suppliers to do the same. Customers by and large are delighted to be part of this new kind of supply chain and are willing to invest time to specify what exactly they want provided businesses are willing to keep their end of the bargain in terms of high quality, timeliness and prompt service. The probability of manufacturing technology graduates encountering demand-driven manufacturing systems that operate on a mass customization paradigm is very high per current indicators. This paper concludes with a synopsis of certain imperatives for inclusion in a detailed examination of the curricula in four year degree programs. Specifically, we suggest that students should be prepared to perform value stream analysis, work towards developing a firm's core competency, and be able to analyze and improve supply chain operations.

Introduction

Much of the twentieth century product design and manufacturing was focused on realizing economies of scale and promoting mass production. The early part of the twentieth century witnessed innovations that led to ever increasing productivity, often heralded as the forerunner to the American wealth and relative economic prosperity. It was during this time that Henry Ford pioneered the first moving assembly line which resulted in slashing the production time of Model T cars from 728 hours to 1.5 hours [1]. More recently, during the 1970s and 80s, productivity took on new meaning when quality was postured as its ally rather than a disabler, and the lean production system exemplified by Toyota touted flexibility and agility as true enablers of organizational throughput as opposed to efficiency and quantity (measuring output regardless of quality as in “doing things right the first time”) [2]. The never-ending quest to eliminate waste in all its forms and improve true productivity has resulted in a continuous flow of newer concepts in manufacturing that include but are not limited to cellular manufacturing, just-in-time inventory, pull systems, six-sigma, and supply chain management [3] .

The savvy customers look for value in most everyday purchases and it is only a matter of time before the others realize the same through personal experiences or otherwise. The term “value” may be operationally defined as quality/price [4]. Quality is a moving target and the term has now come to be more multi-faceted than ever and among other things includes constructs such as durability, reliability, aesthetics, speed, service, [5] and last but not the least, customization. The term “custom-made” is almost always synonymous with high cost but this is becoming less true as witnessed in everyday business today. Customers have more choices than ever before on an increasing array of products and services without having to pay the hefty premium for customization. Industries all over the world are revamping their production systems to cater to ever increasing demand for specialized and customized products at competitively low prices and serve markets of size one. A world class supply management system, thriving on continuously evolving value chain analyses is fast becoming the precursor to successful mass–customization efforts, and is ushering in a new global era in manufacturing [6].

Mass customization as a concept attained prominence in the 1990s with much credit attributed to Pine (1993) for promoting this subject matter and raising consumer awareness [7]. The preparation of technologists at four year colleges faces new challenges in the wake of this relatively new trend in product development. This paper examines the movement towards mass customization with examples included from several sectors of the industry. We provide a brief review of the evolution of product development into its current stage of mass customization and identify certain imperatives that help better prepare our students to take on these new challenges.

From Mass Production to Mass Customization

In some ways, with the advent of mass customization, production systems have completed a full circle. The dawn of the historic industrial revolution spawned the growth of highly localized manufacturing operations, the so called “mom and pop” shops. Customization was the order of the day but only a few privileged among the population were able to afford the high cost of such industrialized goods. The onset of the assembly line system and related mass production techniques lead to the growth of factories resulting in lower cost per unit thus making products more affordable. However, mass production resulted in a “push system” with customers required to buy what was offered with little or no scope for specifying individual preferences. Remember the famous Henry Ford declaration. “......they can have any color they want as long as it’s black” when asked what colors of paint finish may be requested of his Model T cars. And then along comes the idea of mass customization exemplified by the now famous Dell model for building and selling computers and peripherals that can be direct ordered by end –user customers or Nike’s model for selling shoes that can be created largely to customer preferences including but not limited to the design of heel and sole, design of the upper, tether system, and a custom-fit.. Remember that both Dell and Nike are able to offer this customization with little or no increases in cost to the consumer. Dell eliminated the wholesaler and retailer from the business to consumer transaction and passed on significant savings to the buyer whereas Nike charged a nominal extra fee in the range of just ten dollars to provide a custom-fit shoe [8]. With these examples in mind, mass customization is appropriately explained as "…...a paradox by combining customization and mass production, offering unique products in a mass-produced, low-cost, high volume production environment." [9, p. 314].

Mass production relies on the aggregation, consolidation and design of large-scale operations in order to achieve economies of scale and minimize outsourcing thereby attempting to maximum profits for the individual firm. As an example, the Ford Motor Company also owned its steel milling operation in the early 20th century [10]. In mass production, the ability of an individual entity to contribute to the value of the raw material through processing at successive stages and then taking the product to the market until it is sold to the end user dictates both company stature and profits. With engineering, technology, and management all becoming more complex and specialized, companies were forced to focus more on their core competencies in order to maximize utilization of resources and compete favorably thus posing new challenges in the area of supply management, outsourcing, and collaborative product development and marketing. Agility, adaptability and alignment become more important in the current manufacturing paradigm, the era of mass customization [11]. As an example of core competency, consider Federal Express Inc. Their core competency lies in shipping and delivery which has made them famous and earned the respect and patronage of producers and consumers alike. It would be extremely challenging for any producer to outperform FedEx if they were to create their own in-house shipping and delivery system. It is no small wonder that FedEx remains the transporter of choice for various producers through well established alliances, that is, it becomes part of the supply chain operations.

The primary motivation for mass customization is to be able to provide the customer with exactly what they want. By nature, it is a demand driven process as opposed to a mass produced item which is mostly made to stock. It is estimated that only about 1/3rd of all apparel products that are made to stock are produced to exactly fit potential customers [12]; the rest of us make "accommodations." As another example, consider the case of mass produced automobiles; customers may be forced to pay for features built-in they do not need or unable to have certain simple, inexpensive features they really desire and are quite easily provided for in production. The apparel and fashion industry was among the first to use mass customization as a business strategy; the examples of Levi-Strauss (custom-fit jeans), Timbuk2 (backpacks), and Nike (shoes) are frequently cited in literature [13]. Today, the literature uncovers customization across a broad spectrum of industry products ranging from M & M candies to refurbished Ford Mustangs [14, 15]. The mass customization movement is in full swing here in the United States and catching on abroad as well.

Flexible manufacturing systems are a major enabler of mass customization. Reduced setup times and the concept of cellular manufacturing have made it possible to produce economically in smaller lot sizes and in many cases, single lot sizes (eventual target for customization) are achievable. The Internet is another major enabler paving the way for e-Commerce. The business to consumer (B2C) sales model adopted by Dell Inc. in selling PC systems is a case in point [16]. Another key development that has enabled mass customization by leaps and bounds is large scale attention to and improvement in supply management practices. The progression of industrial supply management can be explained in terms of four eras as outlined in Table1 [1].

Table 1: Supply management practices in four generations of modern manufacturing.

Period	***Characterization of Supply Management and Allied Manufacturing Practice***
1776-1912 ***The Industrial Revolution Era***	Heralded by the division and specialization of skills coupled with expanded markets. Witnessed the development of railroads, basic forms of modern transportation and creation of mills and factories. Also witnessed the development of communication networks and expanded global interests across peoples and countries. The availability of new goods restricted to a minority privileged part of the populations
1913-1973 ***The Mass Production Era***	Henry Ford creating the first moving assembly line in 1913. Interest and progress in factory plant layouts to meet diverse needs; further progress in terms of division of labor and specialization. The relationship of larger corporations with their suppliers could be characterized as "divide and conquer" and quite adversarial. A period when American manufacturing established itself as the world's leader and mass produced goods became more freely available. Customized products could be availed at considerably higher prices
1974-1995 ***The Progressive Manufacturing Era***	Recognition of superior manufacturing practices among off-shore manufacturers, notably Japan. Attention diverted to efficient and effective production management practices with emphasis on improving quality of processes. The supply and receipt of goods in industry took cognizance of concepts such as Just-in-Time inventory, theory of constraints, one-piece flow (pull) manufacturing characterized by Kanbans and Kaizen (continuous improvement). Management focus was largely internal to the organization and supplier relations although critical did not see any radical shifts compared to the mass production era
1996- to date ***The Information Engineering Era***	Blossomed as people became more adept at using the World Wide Web for communications and the world of E-Commerce unfolded. Mass production practices yielded way to mass customization challenging industries to collaborate better to provide more value to customers and deliver better products produced quicker than ever before at the lowest possible cost. Management focus expands to include in-depth analysis of supply chain networks. Distribution networks emphasized partnerships across the entire supply chain and it became possible to share critical information in real-time between partners

Before embarking on mass customization of a particular item or a line of item, three fundamentals issues need to be addressed [17]. They are:

- Is the end user willing to pay the required premium for a customized product?
- Is the end user willing to wait for a reasonable time to receive their customized product?
- Is the end user capable of and willing to invest time in "designing" or providing specifications for the product?

Several studies pertaining to the underlying theories of customization and success/failure stories of initiatives are available and the interested reader is urged to explore these for further information [18, 19]. There is really only one major drawback of customization from the end-user perspective; they may have to pay a higher price. However, it is worth recalling that mass customization means customizing at little or no extra cost to the consumer. If the incremental cost of customization is too high to preclude the majority of potential users, then the initiative should not really be deemed ***"mass"*** customization.

Implications for Four-year Technology Degree Programs

The business shift towards mass customization has been more evolutionary as opposed to revolutionary. Much of the curricular reform required to address the mass customization movement have been initiated at several institutions and are included in the ABET-TAC criterion as a response to global wide efforts in the practice of simultaneous engineering, lean systems, just-in-time, total quality management and automated systems. However, existing programs should be investigated to examine whether the curriculum also addresses the remarkable shift from mass production to mass customization. Students in four-year technology degree programs should be exposed to the idea of mass customization and how it is different from mass production or even expensive customization. Of particular importance, the manufacturing technologies curriculum should have a structure that permits learning and applying elements that are central to operations designed for mass customization. Recognizing that the creation of an exhaustive list (if one exists) can be a daunting task, we focus on the following five ideas that would serve as a good starting point:

The success of mass customization efforts depends on value additions ***as perceived*** by the end user. Students should have a good understanding of the term value and be able to carry out modern methods of analysis using value stream mapping. The three broad cost categories in manufacturing are materials, overhead, and direct labor. Experts have pointed out that quite frequently direct labor is targeted to reduce cost (waste) when much of the waste results from the materials and overhead side of operations [20]. Students should be well-versed in systematic and objective value analysis. The identification and minimization or elimination of waste in all its forms is an essential skill that needs to be developed and nurtured.

The emphasis on development of core competencies and life-long learning is critical. Students should have opportunities for developing specialized skills; most degree programs are already structured to permit the choice of free electives. The choice of elective courses should be made to provide an in-depth knowledge in developing a core competency that builds on individual aptitude and skills within manufacturing such as systems, automation, processes, or a specific area of management such as supply, inventory or production. In the experience of the authors, students rarely choose elective courses with proper planning. The need for life-long learning can be infused into the curriculum by challenging student teams to solve multi-faceted problems that involve actual industry case studies where possible, or by posing novel problems based on unmet or even unexpressed needs of society.

Business competition is global and collaborative in nature and the rules of the game are constantly changing. The future of business competition is likely to see more of one supply chain pitted against another and less of one firm versus another firm. Partnerships and alliances will become more complex in character and greater advances in collaborative tools are to be expected. The Internet and related on-line technologies is a given tool for global collaboration and building alliances. The students should have opportunity to use collaborative design tools and be exposed to the concept of value added reseller (VAR) and their products [21]. A majority of emerging jobs in manufacturing belong to small and medium size manufacturers that operate as part of a supply chain and information technologies play a vital role in ensuring real time communication within the supply chain. New technologies such as radio frequency identification (RFID) continue to enhance information technology and students could use practical encounters on these new developments. We should further explore the possibility of involving inter-departmental and inter-institutional projects, preferably incorporating student teams from other countries.

Mass customization efforts require good judgment in terms of postponement. Here, the term postponement refers to the maximum delay that can be accommodated for individual processes or operations in order to promote a "build to demand" as opposed to "build to stock" approach. The concept of modularity is often used to postpone operations to the largest extent of time possible so that the end user can have something they really want and the provider/s can react quickly to changes in demand. The idea is to strike an optimum balance between flexibility and response time [10]. Over the years, several DFX concepts have emerged and discussed in literature where DF stands for "design for" and the "X" could mean any one of manufacturability (M), environment (E), assembly (A) or other design domain [22]. The term "design for mass customization" is yet to catch on but regardless this concept is already widely practiced in industry. At the time of writing, DFC is just starting to emerge as the acronym of choice defining the all too important design domain of customization. As an interesting digression, an on-line search using Google TM [23] with the key phrase "design for customization" yielded 240 versus 252,000 hits for "design for manufacturability."

Quality is a moving target. Any quality problem or shortcoming is trivial only as long as your competition also treats it lightly. Ninety percent could be an A in a college course, but is a failing grade in the real world of manufacturing. In the automotive industry sector, the best Tier 1 suppliers come real close to 100% usually ranging between 98-99%. A 90% perfect order score is widely regarded as a failing score in this sector [24]. There is really nothing trivial about poor quality or failing to meet delivery promises as a supplier because the competition is intense. This statistic for the automotive sector should serve as an eye-opener and widely regarded as the shape of things to follow in virtually all industrial sectors as exemplified in the practice of six-sigma quality and conformance.

Conclusion

We have barely seen the tip of the iceberg in regards to applications of mass customization. Progressive manufacturing practices have always been made possible by new thinking and new technologies. Often, one triggers the other. The age-old question of what comes first, the horse or the cart is often relevant in discussing the interrelationship between new technologies and new ideas. This thought can also be extended to mass customization and its enablers such as information technology, supply chain management and value chain analysis. This subject area provides for plenty of imaginative and potentially fruitful exercises in the manufacturing classrooms. Students should be given ample opportunities to pursue the study of mass customization and its enabling technologies in the manufacturing curriculum.

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