Whatever Happened to Product Realization? Will Technology Programs Succeed Where Engineering Programs Have Failed?

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ABSTRACT - Product design and realization was scrutinized at the 1969 Society of Manufacturing Engineering (SME) Forum on Manufacturing Engineering Education. The organizers were aware of the gap between design and manufacture. However, the topic languished in academia for some twenty years. Between 1994 and 1997, National Science Foundation (NSF) invested $26M on major projects related directly to product realization and manufacturing In the ME curriculum. The executive summary of the American Society of Mechanical Engineers (ASME) report describing this activity begins by stating: "Weakness in design and manufacturing capabilities is often cited as a crucial factor in the decline of this nation's international competition." This paper examines the thrust of contemporary Mechanical Engineering (ME) programs in relation to those of technology. A gap still exists between what ME students are taught and what manufacturing industry needs. Currently programs in technology are filling this gap. However, no opportunity is being offered for Engineering and Technology students to work together as they will be required to do on joining manufacturing industry. The paper concludes with recommendations for collaboration between Engineering and Technology programs.

Keywords: Engineering Curricula, Manufacturing, Technology Curricula

INTRODUCTION

During November 1969 The Society of Manufacturing Engineers (SME) held a Forum on Manufacturing Education,[1], at the General Motors Institute (GMI), (now Kettering University), in Flint Michigan.

The need for 'formally trained manufacturing engineers' had been revealed in an SME sponsored study conducted by Arthur D. Little, Inc. [2]. The meeting convened by SME, involved six (6) distinguished speakers from industry, including such organizations as Ford Motor Co, IBM, Whirlpool, Diebold, Caterpillar, and Western Electric, and six (6) speakers from academia (Boston University, The University of Illinois at Chicago Circle, The University of Bridgeport, CT, Utah State University, and The University of Vermont). Each of these institutions possessed curricula designated Manufacturing Engineering. At that time (1969) they were the only universities in the US with curricula so designated.

The academicians recognized several important dimensions of such programs, for example, materials, processing, computer control, management, and product development.

A noteworthy outcome of that meeting, apart from sparking the awareness of universities to industry's needs, was that many of the institutions represented there indicated that their path towards the accreditation of their programs would be best served by becoming associated with the National Association of Industrial Technology (NAIT), whereas others, (mainly drawn from Colleges of Engineering) would seek accreditation through the Accreditation Board for Engineering and Technology (ABET).

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Interestingly the former NAIT has recently (January 2009) morphed into the Association for Technology, management, and Applied Engineering (ATMAE). Also, since 1969, many of the manufacturing engineering oriented programs became absorbed into Mechanical or Industrial Engineering programs as modest funding became available for research and educational developments in this area, especially manufacturing systems. Otherwise the issue was forgotten.

As mentioned, one of the topics highlighted at the 1969 Forum was 'Product Development'. In 1995 the American Society of Mechanical Engineers (ASME) published the report cited in the abstract of this paper entitled 'Integrating the Product Realization Process (PRP) in the Undergraduate Curriculum' [3], reporting on major projects related to 'product realization and manufacture across the curriculum'. The National Science Foundation (NSF) had invested some $26m on these projects which involved collaboration amongst 35 universities and colleges, many of them major research institutions. This paper examines what has evolved since the publication of this 1995 report by ASME, and summarizes the present situation in Mechanical Engineering as well as Technology programs.

THE 'GAP' THAT HAS RE-ESTABLISHED ITSELF

During the late fifties and early sixties, many industries recognized the serious gap that existed between design and manufacture. In fact, rather than calling this short-coming a 'gap' many rebranded the same as a 'wall'. In the words of a manufacturing staff member who shall remain nameless: "Those designers just throw the specifications of the product over the wall to us guys in manufacturing and expect us to work out the details of how to make it."

Another manufacturing - based individual referred to such designs as 'mechanical onions'. They could not be readily manufactured but perhaps could be grown!

Indeed, the ASME report [3] in its Executive Summary stated: "Weakness in design and manufacturing capabilities is often cited as a crucial factor in the decline of this nation's international competition."

From the above report it appeared that 'model curricula' addressing this weakness were being formulated and in some cases implemented.

It is interesting to examine what has happened since regarding these aspects of curriculum development in Mechanical Engineering, especially in the area of product design and development. Although XYZ University was proud to claim that product design was 'alive and well' in their (1995) ME Department, examination of their current curriculum lists no specific courses in this area, nor in the areas of materials or manufacturing processes. It is difficult to see how such topics can be bundled into a design course rather than be part of a planned design sequence.

Admittedly there have been serious external pressures on engineering educators since this time (1995). These are likely to include:

i. The '120' hour syndrome
ii. The manufacturing image problem ('Dumb, Dirty, Dangerous, and Disappearing' [4])
iii. The change taking place in the profile of the young engineering educator

Looking at these pressures in turn, the curricula described in the 1969 SME Forum occupied anything between 139 and 144 credit hours. Current state legislatures, aware of the 5½ years of study accumulated by the average engineering student, have exerted external pressures to reduce such curricula to 120 hours, bringing things into line with program length experienced by liberal arts students. No doubt these political pressures were partly motivated by the concerns of their constituents whose offspring were following the engineering path.

The image problem has been with manufacturing since at least the time of the Industrial Revolution in England, exemplified by Blake's "Satanic Mills" [5]. It is perhaps partly perpetrated today by the notion 'Let the Chinese make it, we can sell it at bargain prices!' Those responsible for the Industrial Revolution in England were not university educated 'gentlemen' for the moist part but more technologists than engineering scientists. Perhaps Isambard Kingdom Brunel was the last true engineer – or was he the first true engineering technologist? On the other hand, as a result of the Industrial Revolution flowering later in continental Europe [6], the engineering culture involved more scientifically trained as well as widely respected individuals.

This image problem is reflected in the changing of NAIT into ATMAE to represent that technologists are not blue collar workers and that manufacturing industry is not "dumb, dirty, dangerous, nor disappearing".

This respect has undoubtedly survived more in the minds of the public in Germany, for example it has had an effect on recruitment to engineering centered universities, which has in turn contributed to that county's prestige across the engineering profession.

It is thus tempting to draw a parallel with a nation where engineering training is taken especially seriously and where the young engineer graduates with a broad appreciation of the science of manufacture. This approach, taken in Germany, Scandinavia, and to some degree in the Far East, involves exposure to the highly multi-disciplinary aspects of that science such as the mechanical and thermal behavior of materials in processing, the analysis and design of machine tools, the associated fundamentals of metrology and tribology, topics largely ignored in many Mechanical Engineering curricula.

If one examines the overall economics of Germany and other industrial nations it is not difficult to perceive why such rigorous training has contributed to a trade balance of $278.7 billion while the US has slumped into a deficit of $815.3 billion, [7]. This is approximately a $1.1 trillion difference! For a breakdown of the figures for the past decade see Table 1.

Country	Trade Balance 2000 ($, bn)	Trade Balance 2009 ($, bn)	Difference ($, bn)	Average Difference per Year ($, bn)
United States	-245.00	-815.30	-570.30	-63.37
Germany	79.00	278.70	199.70	22.19
United Kingdom	-34.00	-178.70	-144.70	-16.08
Japan	122.40	104.80	-17.60	-1.96
France	26.20	-54.90	-81.10	-9.01
China	46.60	315.40	268.80	29.87

Table 1. Balance of trade data for years 2000 and 2009 for selected industrialized nations [7, 8]. Note Figures in red indicate a loss.

Admittedly much of the US deficit is related to oil imports. However, neither Germany nor Japan are blessed with such natural resources and have skillfully maintained a positive balance of trade through the export of manufactured goods ranging from machine tools to passenger vehicles. Many of the potential consequences of neglect of the above topics in the training of engineers in the US has been pointed out by one of the present authors (T.A.) over the years, [9, 10, 11, 12]

The last of the three 'pressures' has taken an interesting course. The necessity of the young assistant professor eager to teach advanced theoretical and computational graduate courses, to gain research support and obtain academic tenure has, over the current 'generation' , brought into academia many who have little or no industrial experience, and indeed many with no concept of 'how things are made'.

It is perhaps easy to blame this on the funding agencies such as NSF. However, this does raise some interesting questions. Does everyone in academia need to be educated to become an expert in nanosciences, or as of now in biomedical sciences? As a result of this funding driven drift, are engineering students being short-changed? Are they going to become aware, for example, that selecting a highly automated, low cost method of producing a component by one of today's modern casting processes is perhaps more appropriate than a forged or sintered processing route? Could a student see that the machining process they are using can drastically affect the surface finish, not just in roughness but its functionality, which is its suitability to perform the task for which it was designed? We are now going down a route that allows us to simulate everything, but unless clever experiments are undertaken to validate such simulations some of the knowledge will be lost in a series of algorithms.

It may be countered that the teaching of sound engineering fundamentals alone is the best preparation for today's industry – leaving the familiarization with how to develop and economically manufacture a product to industry itself. This in turn, would be countered by industry saying that current international competition does not allow them to undertake this additional training luxury.

It would appear that the 'gap' or 'wall' between the designer/innovator and the manufacturer has been re-established! Except, perhaps, in the current case the 'gap' or 'wall' is often represented (in the US at least) by the Pacific: 'The Chinese will work out how it's to be made.'

THE RISE OF THE MANUFACTURING TECHNOLOGIST

The ‘split’ that was initiated at the 1969 SME Forum between engineering and technology educators led to the technologists listening more carefully to the needs of sustainable industry. This has resulted in the growth and maturation of curricula in Industrial or Manufacturing Technology.

The desertion of many Industrial and Mechanical Engineering departments of their responsibilities in the area of manufacturing, plus the apparent trend of these departments to educate engineering scientists, rather than engineers, has contributed significantly to the growth of technology programs. Furthermore this is emphasized by industry’s acceptance of individuals trained in these alternative programs.

Not only are the technology students concerned fully accepted and indeed highly welcomed by industry, many such graduates often find themselves managing a group made up of engineering school trained individuals! Many Industrial Technology graduates go into industry in Industrial Engineering positions as they have a combination of the theoretical training, hands-on training, and some business courses which make them ideal candidates for manufacturing management positions.

Finally, with respect to technology programs, they produce graduates who truly possess the necessary skills for manufacturing industry. These technology programs need to align and ally themselves with their engineering counterparts. This is to ensure that the wall between design and manufacture is permanently torn down. This will lead to a cross-fertilization of ideas and curricula to produce both high quality technologists with a science background and to provide engineering students with a glimpse of manufacturing. Furthermore, this will permit them to work in “real world” teams on class and term projects. Interestingly enough two of the authors (J.E.W. & J.T.B.) tried to undertake and experiment of this type where the students (both ME and Technology) had to design and build a small tilt-pour casting rig. Unfortunately, in the end the technology students went ahead and built the device, while the engineering students just drew the design that the technologists had built. It is clearly; that we still have a long way to go to have a truly concurrent engineering philosophy instilled in both technology and ME departments.

However, all is not wine and roses with Technology programs. Indeed, a number of meaningful improvements must be brought about:

1. Students of Technology need to be made more appreciative of the physics underlying the many suites of process simulating software now available, without becoming expert in the writing of such code. The same is true in terms of their understanding of the analytical and computational limitations of such software.
2. They also need to be afforded the opportunity of working alongside engineering students, implementing a truly concurrent engineering approach, just as they are to work on joining industry.
3. Where possible, such programs should be housed in Engineering Colleges rather than in Colleges of Education and/or Business. Where this is not possible internships, which allow them to meet and work with engineers in industry, would be highly desirable.
4. It is inappropriate to regard the technology graduate as a second class citizen.

CONCLUSIONS

1. Mechanical Engineers have become scientists who frequently regard computer tools as the principle means of solution of industrial problems. However, successful simulation requires careful validation prior to implementation. This stage at present is frequently left to the technologists as they alone possess the necessary skill sets to bring about this final highly essential implementation stage.

2. Ought one to say that Mechanical Engineering programs have somewhat arrogantly handed the manufacturing tasks to technology programs as a result of the way new engineering educators are trained. For their part Mechanical Engineering professors largely ignored manufacturing science, as has been pointed out earlier. These topics are highly multidisciplinary and require knowledge of the real practical world. Young PhD’s without any knowledge of the real world would of course rather focus on theory and on the solving of often neat but hypothetical problems that do not emulate reality. As a result, for example, the US machine tool and die making industries have seriously declined. Consequently, the best machine tools are now imported from Japan or Germany and tooling from China.

3. The image of the technologist as being a second class citizen in the eyes of engineers needs to be addressed. His/her role is vital if any industrialized nation is to prosper. This can only happen through its capabilities to innovate, design and actually manufacture such products as machine tools for example. While the US still leads

some areas such as software, biotechnology, communications, our lead in producing goods for export has eroded as a result. While among industrial countries, Germany, for example, has a trade balance of $278.7 billion while the US has slumped into a deficit of $815.3 billion, [7]. Germany and Japan has been able to protect living standards due their manufacturing capabilities. The US on the other hand is on the verge on lowering its living standard. Meanwhile, academics write papers and worry about increasing the ranking of their institution. Consequently the world is passing us by. If the manufacturing core of an industrialized nation dies then that nation will become a third world country with simulation based engineering, some modest technology, and whole lot of people in the service industries.

4. The manufacturing profession is now firmly established in the technology camp. However, there must be an effective integration of the two disciplines by bringing together their respective students during their training. Engineering needs to learn how to communicate successfully with the manufacturing technologist. In this way the 'wall' between design and manufacture would eventually be demolished.

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BIOGRAPHICAL INFORMATION

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Dr. John T. Berry is a fellow of both the American Society of Mechanical Engineering (ASME), and the Institute of Cast Metals Engineers (ICME). He obtained both his B.Sc. (Hons) and PhD at Birmingham University in the United Kingdom. His research interests are broad and include solidification processing, machinability, specialized mechanical testing and the manufacture of musical instruments. He joined the faculty of Mississippi State University in 1995. Previously he held chairs at Georgia Tech and the University of Alabama. He has roughly 200 publications, many of which are concerned with cast materials. He serves as the Foundry Education Foundation (FEF) key professor at Mississippi State. Last November he received the Distinguished Professor Award of FEF and the American Foundry Society (AFS).

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Dr. Taylan Altan received his Diploma Engineering degree from the Technical University, Hannover, Germany and his MS and PhD from the University of California, Berkeley. After working two years at DuPont and 18 years at

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