# Preparing Undergraduate Mechanical Engineering Students for the Global Marketplace—New Demands and Requirements

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***Abstract***

With the maturity of such technologies as the Internet, advanced design and analysis software, and database management software, more and more companies are shifting to a Product Lifecycle Management (PLM) software base in which engineering activities are now located in cyberspace, as opposed to any particular geographic location. In fact, if current trends continue, U.S.-based multi-national corporations will become less and less dependent on continental U.S. engineering services, and more reliant on offshore providers. Current corporations such as the Boeing Company are already moving to "24/7" engineering cycles for new aircraft, with engineers around the globe working on the same shared parts and assemblies in their respective countries as the world turns. As large corporations like Boeing, Daimler-Chrysler and Black and Decker implement true paperless environments, with suppliers and manufacturers alike sharing information in a centralized digital model, corporations with engineers that are not educated in PLM methods will be obsolete.

Because of the cost differential between engineering services in the U.S. and other cheaper alternatives in countries such as India, U.S. graduates will need to have a value-added increment to justify their higher salary requirements. In this paper, the authors take a case study approach toward understanding the educational needs of mechanical engineers that academia supplies to various multi-national corporations, and suggest a curricular revision roadmap necessary to accommodate these changes. In particular, the vehicle to carry these curricular changes to fruition is the same set of tools that industry is currently using—PLM software. In the PLM environment, students can quickly access a variety of analysis and design tools that offer the ability to increase understanding of system physical behavior, as well as augment important problem solving abilities.

## Introduction

If there will be one story remembered regarding job growth and creation in the first decade of the 21st century, it will be the phenomenon of business process outsourcing (BPO) experienced by professions as diverse as information technology to legal online database research. A study done[1] by the University of California at Berkley indicates that U.S. companies in the Indian press announced 25,000 to 30,000 new outsourcing jobs during the month of July. Meanwhile, there were 2087 mass layoff actions carried out by U.S. employers resulting in the loss of over 226,435 jobs.

When discussing BPO trends, the most notable candidates recently have information technology (IT) jobs, and their rapid transmigration to India. There has also been some outsourcing of electrical engineering jobs. Companies like LM Ericsson, as part of a strategy to gain greater efficiencies and economies of scale in development, are basically engaging in merger-type activities with Indian partners, thus accessing lower labor rates and a broader pool of intellectual capital. Cisco Systems of San Jose, CA is also engaging in similar activity by working with Indian companies in addition to the work done with its own center in Bangalore[2].

With respect to mechanical engineering, many firms such as Black and Decker[3], Boeing, Daimler-Chrysler and their suppliers, are already interconnected with technological development activities in a variety of ways. In interviews with integration managers at the Boeing Company, the rationale for a global engineering effort becomes obvious. As Boeing is one of the major export manufacturers in the United States, contracts between Boeing and respective country-based airlines depend on a certain amount of airplane content being built in that respective country, with Boeing serving as the large-scale integrator of airplane parts made literally around the world. A major driver for large multi-national corporations in pursuing such growth paths involves not only potential cost savings with respect to engineering service costs, but equally or more important, access to intellectual property from around the world. The intellectual economies of scale achieved by a multi-national effort, when managed properly, can be tremendous. Since 70% of Boeing's market is overseas, neglect of concerns from customer countries can only contribute to loss of market share.

## The Affected Demographic Class

Engineers at the start of their careers are very vulnerable to BPO corporate efforts. Since this is a recent phenomenon, especially with regards to engineering, hard figures are difficult to come by. However, plots of mechanical engineering starting salaries over the past ten years show that engineers have made no real monetary gains once the salary data is adjusted for inflation (Figure 1)[4]

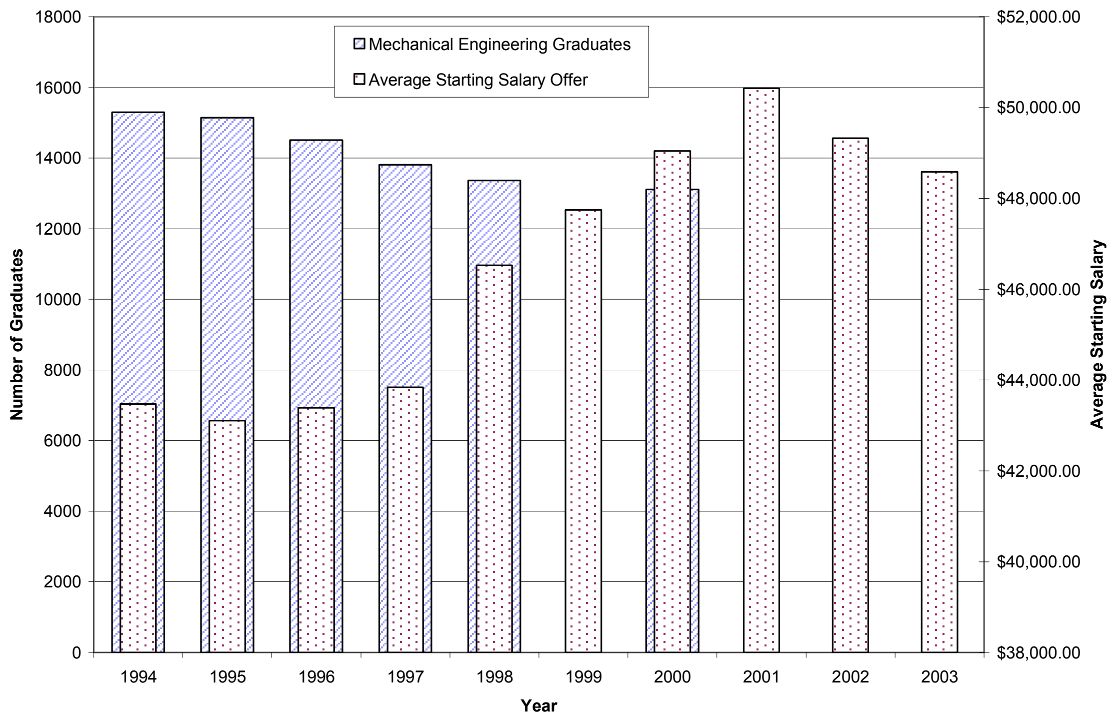


Figure 1: Mechanical Engineering Graduates and Average Starting Salary

While there is some correlation between decreasing demand and increasing salary, the connection is tenuous, as salaries at most grew only 1-2% in real dollars, while the number of graduates declined by over 20% (Figure 1). These figures do not show if the number of non-domestic students in the US ME programs has risen or declined. However, other data suggests that the number of foreign students has risen over the past few years, leading us to the conclusion that the number of domestic ME graduates has declined drastically.[5] Certainly, the gains in productivity of the individual engineer due to the rapid spread of sophisticated computer technology over the last ten years is a factor that has suppressed demand for new engineers, even while the U.S. economy was going through one of the largest, most consistent expansions in history. During the current shrinking of the US economy, it is becoming obvious that BPO activities will further suppress demand for domestic graduates.

**Case Studies/ Suggestions from Industrial Partners**

Interviews were conducted with engineers that work in two separate companies regarding the effects of the new global marketplace for engineering services. The first, Ogihara, Inc., is a multi-national corporation, based in Japan that provides tool and die services for the automotive industry. Ogihara provides full service tool manufacturing and maintenance capabilities, as well as also providing high-quality body panels for automotive manufacturers.

A senior design engineer was interviewed regarding the use of PLM in improving Ogihara's customer service and support.[6] Ogihara uses an Indian subcontractor for checking revision changes on parts that they are going to build, in order to insure that the die accommodates the change. There were a couple of chief advantages for Ogihara with respect to outsourcing engineering work. First was the low cost of Indian engineering labor. Typical charge rates for Indian labor is $15-$16/hour, with $7/hour going toward the engineer's salary. The second main advantage was due to the time zone difference between India and the U.S. A project sent to India at the end of working day can arrive on the responsible engineer's desk completed the following morning, ready for implementation.

One of the main deficiencies in newly minted U.S. graduates that was noted by this engineer was the lack of fluency in a variety of software tools, such as Excel, PowerPoint, and other presentation tools, where their Indian counterparts have a high degree of skill that makes them more effective in providing entry-level services. However, the engineer also noted that all work from India is carefully reviewed for technical errors and omissions. Lower level work is the primary work sent overseas. Since the non-domestic partners do not add a great deal of value to the finished product, the lower cost of their efforts makes a certain amount of sense.

The second set of interviews was given to two upper level integration managers at Boeing. Boeing exports 70% of its commercial aircraft production around the world, and has a series of complex manufacturing contractual agreements regarding their airplanes with the various national carriers to whom they provide. Boeing maintains its core competencies and advanced level of expertise in aircraft design and large-scale integration of components. However, many of the various parts of the different aircraft models are manufactured, inspected, and certified in plants located around the world.[7]

The main reason that Boeing is using engineers from around the world is access to what might be called intellectual economies of scale. Through multiple agreements with other companies around the world regarding intellectual property, Boeing gains access to proprietary information and specific areas of expertise in a la carte fashion. This results in cost savings regarding development of those technologies, and also shortens the time-to-first-flight of an airplane. Cost savings regarding engineering labor are not the primary driver in outsourcing at Boeing. However, Boeing has maintained its focus on retaining the higher-level competencies of engineering integration, which place its focus up the engineering skill pyramid. Boeing is especially placed in a competitive crunch in commercial aviation, as their primary competitor is Airbus, which is subsidized by its European participants.

These companies are extremely different in size, motivation, and scope of their activities. However, both have learned to successfully use global collaboration of engineering efforts for specific reasons. Both are retaining high-level core competencies, while farming out either component-level work, as in the Boeing Company, or basic data stream checking, as in Ogihara. When they were asked if mastery of PLM skills and improvement in core computer competencies would reverse this process of globalization, both sets of interviewees indicated that it would not. The compelling benefits of both intellectual economies of scale and detail specialization are benefits that can only be gained with globalization. However, both the authors and interviewees agree that starting engineers, without these core competencies, and fluency in state-of-the-art design tools, will be left out of future activities in systems integration. This level of seamless collaboration and sharing of the design and production efforts will be one of the keys to corporate survival in the 21st century. If we, as educational institutions, do not adapt to the demand for new skills in our graduates, then these graduates will not be able to participate in the workplace.

**Structure of Solutions**

How do we as engineering educators respond to global demands to make our graduates more productive, effective learners? How do we give them the skills to let them contribute value to an enterprise at an earlier stage of their career? One set of answers is available by mimicking the adaptation of PLM software across the curriculum. The same set of tools that allow corporations in the U.S. to increase their intellectual economies of scale can do the same for academia. PLM does this by allowing cross-disciplinary examples to be used repeatedly in a number of classes, joined by a common database. PLM software allows quick parametric analysis of systems, giving students insights into the behavior of mechanical assemblies by making available multiple solutions to a problem class in a short amount of time. PLM also attacks the main problems in the contemporary curriculum: fragmentation and lack of depth. It does this by giving students a sophisticated analysis and visualization tool that enables them to not only improve their problem-solving and design skills, but importantly improves their understanding of the behavior of engineering systems.

Product Lifecycle Management software provides a collaborative development environment that fully integrates engineering analysis, visualization, and manufacturing around a Product Database Management (PDM) system. Software tools made by a multiplicity of vendors, providing analysis and visualization resources including finite element analysis, fluid flow and heat transfer analysis, and system dynamics are all bound together by a PDM that controls access to model revision, interconnection information between sub-assemblies, and document management and control for all related technical information.

Because integration of different tools is seamless to the end user, students can draw an engineering assembly of interest using the visualization tool, then quickly run a stress analysis using the attached finite element package, and do a parametric analysis to understand the behavior of the system. Currently, in most theory/analysis classes such as Thermodynamics or Strength of Materials, students solve approximately 50 problems in a single semester. The primary focus of the problem sets is usually practice involving a particular problem-solving technique. And while mastery of a given problem-solving technique might be a desirable outcome, for most students, the only outcome they get is how to solve problems that the students think will appear on an exam. Very little interpretation of the solution occurs, and the student never builds a base of understanding regarding the actual behavior.

Below is an example of a PLM- based analysis of a cantilever beam with a single support. The PLM tool clearly shows the effect of moving the support in a parametric fashion, as well as the deflected shape

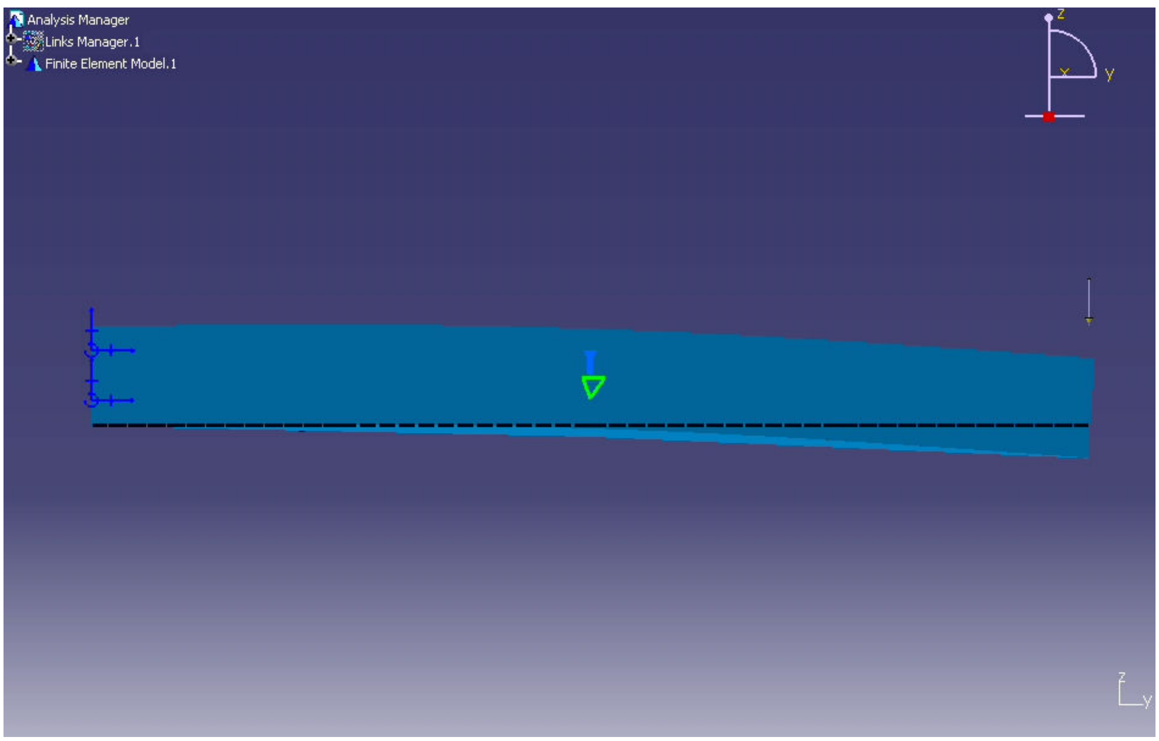


Figure 2: Displacement of a cantilever beam supported one quarter down its length

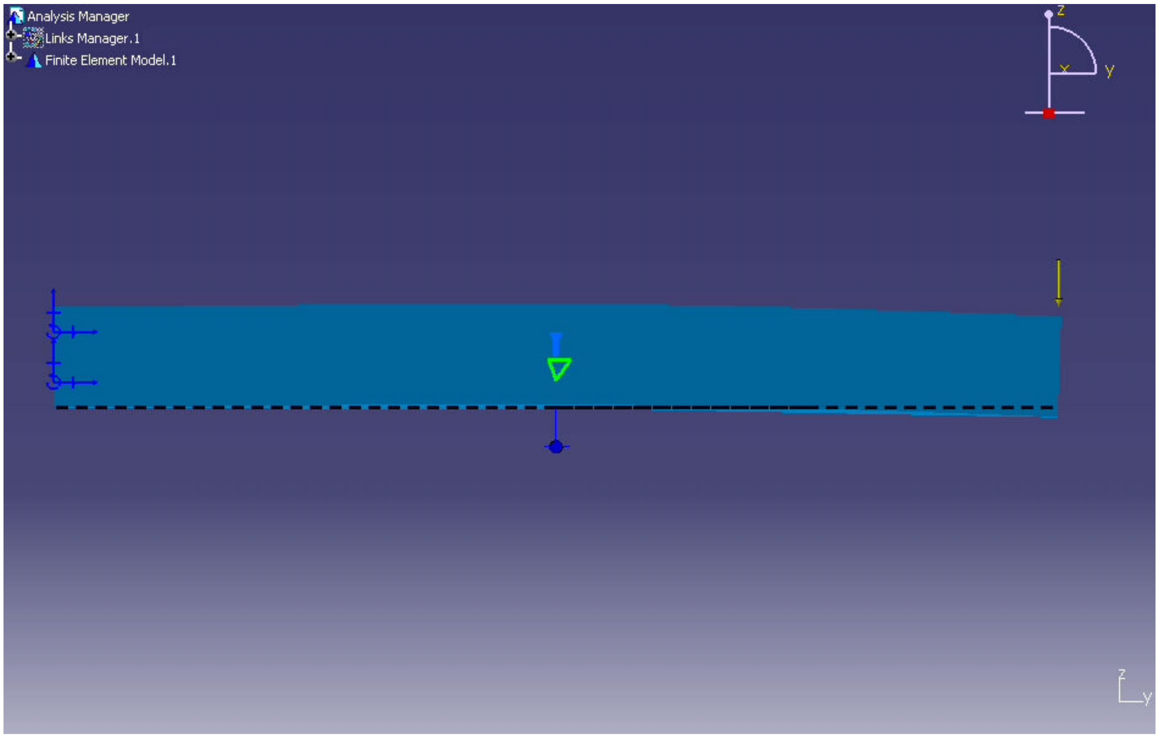


Figure 3: Displacement of a cantilever beam supported half way down its length

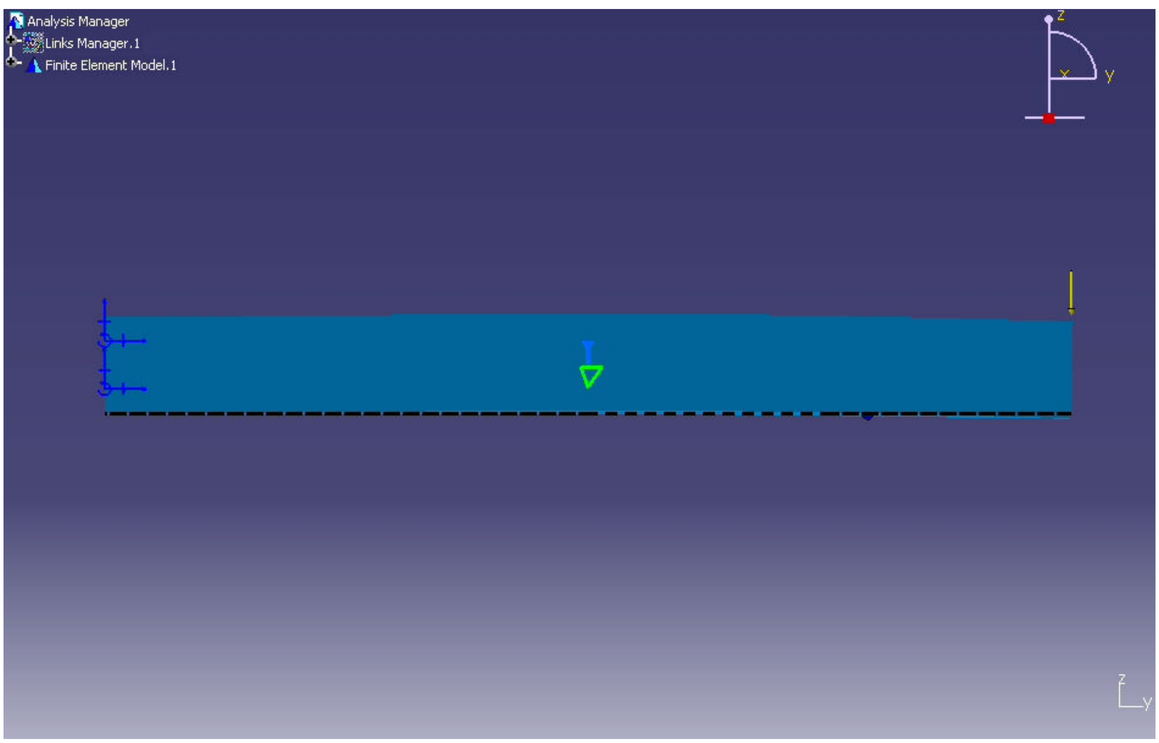


Figure 4: Displacement of a cantilever beam supported three quarters down its length

## A New Paradigm for Curriculum Development

Since we are proposing the addition of PLM solutions to the undergraduate curriculum, we should also consider a curriculum that organically arises from the PLM method. A primary advantage of PLM methods is that the overall requirements for the system are clearly and unambiguously recorded before any thought is given to the actual design of any component. After these requirements are finished, any component that meets them is by definition correct, and any that does not will not suffice. In the case of such a curriculum, the requirements can all be based on a combination of skills that an entry level mechanical engineer must have when he or she applies for a job, combined with long-term conceptual skills that will serve the engineer through their entire career. Such a requirements document must be formulated by a combined team of industrial representatives and faculty of the department attempting the implementation. At WSU, members of our Industrial Advisory Board are actively engaged in PLM projects in their companies. The real challenge in drafting such as specification is securing faculty buy-in. Many faculty are completely unfamiliar with PLM methods, which emphasize a generic, widely applicable method of engineering practice. Educational investment and career incentives for faculty must be a priority, or any attempt will fail.

## Implementation Steps

The lesson that globalization teaches us is that our graduating engineers must be able to add two to three times the value to a product that their non-domestic competitors can. After speaking to our interviewees, changes in the curriculum will require a few modifications.

First, PLM skills, including visualization, database management, and built-in calculation tools, such as finite element analysis are becoming a basic job requirement. Entry-level engineers must be able to quickly and rapidly develop a verifiable prototype inside the computer, as well as provide baseline stress and heat transfer analysis for parts. The PLM environment is the only current tool that allows this. Such instruction will actually benefit students' analytic skills, as this will also allow professors to emphasize understanding system behavior, as well as a diverse set of problem-solving techniques.

The second change is that the engineering classes must add a formal section that teaches the students how to use all of the features of the Microsoft Office suite and project planning software. Currently, the students at WSU are expected to pick up the various skills as they progress through the curriculum. Unfortunately, the consequence of this is that the students only have a baseline level of competency, and many are unaware of the advanced features that are available. The two purposes of the software are to clearly present data, either in a written or multimedia format, and to allow collaboration of engineering teams.

Last, steps must be taken to insure that the students are skilled writers, and are familiar with professional writing styles and levels of content. If they cannot write well, the skills they learn using office software packages will not help them.

The best way to teach the above topics is to allow the students to participate in an immersive engineering environment. A summer intensive would allow students to learn in an immersive environment, while not requiring deletion of classes currently in the engineering schedule of study, and would also help maintain the level of graduates completing degrees in the required four year term. Additionally, longer educational sessions will facilitate student creativity, and break them of the "Lesson of the Bells" that John Taylor Gatto so succinctly summarizes.

> "But when the bell rings, I insist that they drop whatever it is we have been doing and proceed quickly to the next work station. They must turn on and off like a light switch….Indeed, the lesson of bells is that no work is worth finishing, so why care deeply about anything? Years of bells will condition all but the strongest to a world that can no longer offer important work to do. Bells are the secret logic of school time; their logic is inexorable. Bells destroy the past and future, rendering every interval the same as any other, as the abstraction of a map renders every living mountain and river the same, even thought they are not. Bells inoculate each undertaking with indifference"[7]

If students are to succeed, they must strive to add more value in less time than their competitors. If we continue to follow the ageless tradition or fragmented and partitioned teaching, instead of adding a rich and totally immersive learning environment, the "lesson of the bells" will continue. This, in turn, will remove value from our domestic engineers and make them less able to compete in the global marketplace.

A last point to consider is this: If we change our curriculum, and make a concerted and long-term commitment to producing world-class engineers, success is not guaranteed. Many factors beyond the control of any of us might prevent our engineers from receiving the recognition they deserve, and triumphing over our non-domestic competitors. However, if we do not implement changes to our curriculum, we will produce engineers who are less and less able to compete on the world marketplace. This lack of success is guaranteed, and something we should all strive to avoid.

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