Reality Based Teaching In Technology Education

Peter Fleckenstein
St. John Fisher College

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Peter Fleckenstein

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Dr. Lucia Guarino

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TABLE OF CONTENTS

Abstract.................................................................................................3
Introduction..............................................................................................4
Literature Review...................................................................................7
Methodology...........................................................................................12
Results and Analysis...............................................................................16
Discussion...............................................................................................31
Appendices.............................................................................................35
Bibliography............................................................................................40
Abstract

Technology education is a diverse and dynamic academic discipline. As such it is virtually impossible to possess and maintain expertise in all that it encompasses. One method of helping a teacher gain proper insight and perspective into the essential content of a course is through participation in an externship. This study called for getting the teacher out of the classroom and into industry (specifically the design/engineering field) in order to witness first hand the skills and processes necessary. Seven design/engineering firms were visited and consulted. Data gathered from interviews and observations can be applied to develop a more relevant technology curriculum.
Introduction

Eight years ago I made the decision to change my career from the building trades to the teaching profession. This decision was made with the expectation that I would be combining my skills and experience in woodworking and construction with my desire to work with young adults. I chose technology education because the curriculum offered a variety of courses that most closely matched my areas of expertise and interest. This curriculum also appealed to me because of its emphasis on project-based, hands-on learning. The academic training I received at SUNY Oswego in technology courses such as Metals, Energy, Electronics and Drafting was useful in that it taught many of the hands-on skills and concepts used when processing materials and designing products. What the training did not provide was real world practice for the more current technological content that I would one day be teaching. I have discovered since becoming a technology teacher that while there have been opportunities to use my prior construction skills and the information that I learned in formal technology classes, a number of the courses I currently teach have a curriculum for which I have little working knowledge or experience.

According to results of the Technology Education Programs Survey 1998 conducted by T.I.E.S magazine, technology teachers from across the United States teach over 1,700 different course titles. In the two years I have been teaching at Victor High School I have taught seven of the ten technology courses offered including: Design and Drawing for Production, Communications Systems, Graphic Communications, Transportation Systems, Energy and Power, Materials Processing and Manufacturing Systems. Next year I will be teaching yet another course entitled Computer Integrated Manufacturing. While I enjoy the challenge of teaching this variety of classes, I often have a degree of uncertainty as to what information and
practices are truly essential for my students to know; the breadth of my knowledge is not as expansive as such diversity of courses requires. The New York State Department of Education is helpful in that it provides curriculum guidelines and standards for many of the technology offerings, but not for all of them. And while the curriculum guides address the issue of occupations that relate to the course, they do not direct the teacher as to what skills are truly essential in industry or business. Because the guidelines from State Education are general and the needs of industry are specific, I have tried to balance my curriculum with additional books and resources. This, however, is not the best practice.

One of my ongoing objectives in teaching technology is to provide my students with course content that will be meaningful and relevant to their personal growth and future employment skills. This became especially true when I moved from the middle school level to high school where students are just a few years or even months removed from the job market. In order for these students to be prepared for the realities of employment, they need to have some sense of the skills and expectations awaiting them.

Grant Wiggins writes in Educative Assessment 1998 (28), that in order for student work to be meaningful and relevant, it should be authentic in its composition. True authentic work should replicate the types of problems and performance challenges faced by adults in their professional work environments. In a desire to continue to develop a course curriculum that both my students and I will find interesting, meaningful, and relevant, I intend to investigate the practices and problems faced by local business. I will focus my research on the benefits of getting the teacher out of the classroom and into, specifically, the design/engineering industry. By interviewing, observing and surveying professionals in the design field, my hope is to develop an understanding and appreciation of the practices, expectations and essential elements
found in this field. It is hoped that this experience will allow me to validate those elements that I am currently teaching effectively and correct or improve those that are misguided or ineffective.

The focus of my research will be the design/engineering process with the intent of implementing these findings into my Design and Drawing for Production class (DDP). DDP is an engineering based course whose emphasis is on the design and problem-solving process. I anticipate that my findings will enable me to establish a classroom atmosphere that is more representative of what might be found in the workplace. I would also hope to then challenge my students with design problems that are more relevant, and true to what they might experience were they to pursue this professional field.
Literature Review

While the concept of placing a teacher into a business or industry work experience sounds fairly straightforward there has been surprisingly little research done on this process. In searching academic and business resources for research articles, tangential information was found on topics such as professional development, authentic performance, school to work, vocational education, job shadowing and internships. These topics provided insight into some of the questions posed. However, the term that came the closest to the research I am proposing is called an educator externship. A modified version of this program then became the focus of my research.

There are a number of programs in the United States that have been created with the intent of fostering student interest and skills in the world of work. Programs established as a result of the School to Work Opportunities Act of 1994 were designed "to ensure students a seamless transition from secondary education into meaningful, high quality employment and/or further education" (Brustein and Mahler 1994). This law provided opportunities for students to get involved with workplace experiences such as job internships, apprenticeships and school to work programs. Another well established program is vocational education. These programs are designed to show students what they are likely to experience on a daily basis in their chosen field and to teach the skills necessary to succeed in that field. While Technology Education is not entirely vocational in its scope, it is in many ways aligned with this mission. The Technology Education program evolved out of what was once Industrial Arts and later Shop class. In addition to the name change there was also a shift in curriculum emphasis from machine and hand skills to the design and problem solving processes (Schultz).
In a field that is changing as rapidly as technology, teachers should expect that their knowledge and skills would become outdated quickly (Bybee and Loucks-Horsley 2000). In an article on teachers entering the workplace, Kelly Blassingame concurs that the rapid changes not only in technological capability but also in workplace philosophy can make it difficult for teachers to stay current on the skills and aptitudes employers are requiring. The concept behind the educator externship program was to establish an opportunity for teachers to get current with the trends occurring in local business and industry environments. By getting away from the confines of the school building and the ubiquitous textbook, the teacher can experience how the curriculum relates to real work world. An externship can give educators a close-up look at the skills necessary for students to function and excel in a given field. After all, “how can teachers understand and demonstrate how the skills and concepts being taught in their classrooms apply to various work settings if they have not worked or observed in business or industry for some time – or ever?” (Luft). The program enables teachers to gather first-hand insights about the content they are delivering to their students.

A report by the Education Commission of the States (1996) supports this proposal by recommending that employers and business leaders provide professional development not only for teachers but also for counselors and administrators. “For these teachers to be more relevant, we need them to get out ...[of the classroom and into the workplace]” (Luft). Effective professional development must pay attention to three key points. First, teachers need opportunities to deepen their content knowledge. Secondly, teachers need to combine content knowledge with what they know about learning. Thirdly, teachers need tools to help them continue their own leaning (Luft). The concept of putting teachers into the field is not new but
with the number of programs placing emphasis on readying students for life after school this type of professional development is becoming more of a necessity (Eppard, 1998).

An externship commonly lasts between two and six weeks although some placements can extend for an entire school year (Alders, Luft, et al). According to Vernon Luft, director of Externship for Educators in northern Nevada, the primary reasons given for participating in the educator externship program were to gain experience in the business world in order to create a more relevant educational experience for students, to improve the skills taught in the classroom, and to collect ideas for curriculum revision (Luft, Vidoni). For most teachers, such “school to work” internships are a first look at the business world. Many public school teachers went directly from college to the classroom and have never done any other professional work (Cooper).

According to the Educator Externship Program for School to Career Partnerships in western Colorado, teachers who have participated realized a number of benefits from their experience. Most of the teachers indicated that they had become more aware and appreciative of the aptitudes and competencies required in the workplace. Many noted that they had gained a more realistic perspective of the skills students would need to succeed in the workplace. There were those also who indicated that the externship experience had enabled them to gain information and materials that would assist in the design of their curriculum. Other notable benefits of the program included an enhanced sense of subject expertise, an awareness of the pathway potential in some areas and finally an opportunity to develop ongoing links with local businesses (Bennet, Milicevic, and Dolan 1998 and Brown 2000). Benefits cited by other externship programs included the opportunity to learn about the job duties and activities for which a job occupant was responsible and how employees gained and continued to maintain qualifications for their
respective jobs (Luft). The school to work program "... kind of updates a teacher's knowledge of the real world out there... teachers are pretty isolated from the careers that their students are going to go into" (Cooper).

There are a number of groups including federal and state commissions that are advocating for the development of industry and occupational skill standards. This legislation seeks to improve the link between educators and employers by pushing to clarify the skills and related curriculum that are necessary in industry and other occupations (Bailey 1997). There are some, however, who are suspicious of the emphasis being placed on preparing high school students for work. The concern is that a business-oriented curriculum will distract from academic content (Erickson 1999 and Henry 2001).

In the Rochester, New York area, there are several organizations whose objective is to promote industry and create a professional awareness by putting educators and students in contact with business. The Rochester Area Career Education Collaborative (RACEC) was established in 1976 and as of 2001, has partnered more than 560 educators with different industries through their Educator Internship Experience. The Finger Lakes School to Work Consortium is also in the business of placing interested teachers in working environments that relate to their area of teaching instruction.

According to the constructivist perspective of education, students will learn more effectively if they take an active role in the education process rather than being passive recipients of information. Programs such as those offered through RACEC and Finger Lakes Consortium present students with practical applications for the work that they are studying, and makes the curriculum more important and relevant and therefore more effective.
In *Designing Professional Development for Teachers of Science and Mathematics*, Susan Loucks-Horsley notes that the benefits of participating in a work immersion program similar to an externship provide an opportunity to engage in real work that the teacher can take back to the classroom. The idea is to teach the process rather than accumulating facts and to open up channels of communication between scientists and educators. The goal of this professional development strategy is not only for teachers to implement a new curriculum but also for them to strengthen their content and pedagogical knowledge and skills (63). Teachers need to have a deep understanding of important fundamental technology concepts and processes. If technology teachers do not deeply understand the concepts that they are trying to teach, students cannot be expected to learn (Loucks-Horsley).
Methodology

This study was designed to gather information relevant to the question of what engineers/designers do and what skills or aptitudes are deemed essential for student success. This research will ultimately be incorporated into my Design & Drawing for Production course with the intent of making class content more relevant and meaningful. In order to gather this data, I visited engineers who work in local industry in order to clarify what it is that they do and to witness their processes and practices first hand.

Participants:

The first step of my research required locating and identifying potential local businesses and individuals who were involved in the design/engineering process. I focused on contacting companies and individuals I felt produced a product that the students in my Design and Drawing for Production class would find interesting and germane to their age group. Some of the companies selected were in the immediate vicinity of Victor High School. This was done to increase the chance that students would have some familiarity or association with the company or its product thus piquing interest when references were made. All other company selections fell within a twenty-five mile radius of school.

A variety of resources were used to identify and contact these potential companies. For example, the Ontario County Business Council (OCBC) provided a thorough listing of companies located within their county borders. In addition, the OCBC web site included a brief description of the work each company performed as well as a way to contact them. The school-to-work coordinator at Victor High School also provided a listing of companies who had been willing participants in forming work-school connections. Additionally the Yellow Pages advertised an extensive listing of companies under the “engineering” heading. St. John Fisher
Career Services provided valuable leads and the Rochester Democrat and Chronicle and Daily Messenger newspapers were also used to identify possible sources for local engineering stories. Finally, personal friends and acquaintances with experience and/or ties to the engineering profession proved to be an invaluable networking source for leads and information.

Initially my research proposal called for visiting three companies. I realized however, that three visits were not going to provide enough diverse insight. Ultimately, eight companies, two professional organizations and two high schools were visited and consulted. In total, seventeen informal interviews were conducted regarding experiences in the design and engineering field. In every instance I had the fortune of meeting with company, organization or school representatives who had a clear sense of the role of engineering in product development.

Data Collection

Tours and interviews for this research took place at the following businesses: Kodak (Building 214 in Greece), Premier Packaging (Victor), OptiPro (Ontario), G.W. Lisk Company (Clifton Springs), Hoercher Tool & Die (East Rochester), and Terry Precision Bicycles (Macedon). Visits and interviews were also conducted at Ergonomic Solutions at Work Inc. (East Rochester), Sear-Brown Associates (Henrietta), the Rochester Engineering Society (Rochester) and Rochester Area Career Education Collaborative (RACEC). Finally, Project Lead the Way programs at Pittsford Mendon and Palmyra Macedon High Schools were observed as well.

The protocol of gathering information from these individuals varied somewhat from visit to visit based on the personality and agenda of the host. In each case, formal questions were asked pertaining to design and engineering as it was carried out at their business. These questions revolved around the processes that engineers go through when designing. Questions
also dealt with their particular background skills and aptitudes and what was needed to succeed in their line of work.

At some visits these questions were posed as I toured the design/manufacturing plant of a particular facility; in other instances I sat down with my host and posed my questions point by point or as informal conversation allowed. Data that was collected during these visits was later analyzed to identify the most significant and common elements.

**Basis for this research**

The course that stimulated this research is Design and Drawing for Production (DDP). DDP is an introductory technology course developed to introduce students to the design and problem solving processes. DDP is a yearlong course offered to 9th through 12th graders. The two sections that I am teaching this year are composed mainly of freshmen and sophomore males. In one class there are two girls and twelve boys; in the other class there are fourteen boys and one girl. DDP is an elective course that may be used to fulfill the New York State, Art, Music and/or Foreign Language requirements. Consequently, not all students are fully invested in the concept of designing and drawing for the sake of production or in the pursuit of engineering for that matter.

The academic composition of these classes spans the intellectual, social and emotional spectrum.

Emphasis in this course is placed on using sketching and computer drawing methods to produce design solutions to design problems. In past years emphasis was placed on the drawing process with occasional opportunity for product design work. The design aspect has become even more evident this year with the introduction of the Project Lead the Way (PLTW) curriculum. PLTW is an engineering and design based curriculum that stresses the elements that go into the composition, design, and presentation of a product. There is no machinery for model
making or prototype development in this classroom nor do these students have an opportunity to use the machinery in the technology lab during class time. This is mentioned only because students are limited in the extent that they can create models and prototypes of their design work.

We are currently limited to clean, easily cut materials.
Results and Analysis:

The major concepts that surfaced from my research include the scope and impact of engineering, the engineering design process, achieving optimization, the KISS philosophy, communication and collaboration, and the state of the engineering profession. As a teacher responsible for providing my students with meaningful learning opportunities it is essential to have a clear vision of what those outcomes should be. It becomes equally important that those outcomes are based on real practice as opposed to a perceived reality. One of the first realizations that was made at the beginning of this investigation was how limited my perception of the scope of the engineering field had been.

Engineering /design as a ubiquitous entity

It was known but perhaps not fully appreciated just how ubiquitous the process of engineering and design really is. A simple search through the Yellow Pages demonstrated that there are a number of businesses providing a range of engineering specialties in the Rochester area. It was discovered that “engineering” and “design” come in a much wider array of headings and categories than I had stopped to consider.

According to the Rochester Engineering Society (R.E.S) there are a spectrum of engineering specialties ranging from those most familiar such as civil and mechanical engineering to the more obscure such as agricultural and fire protection engineering. R.E.S. publishes a brochure targeting high school students that lists at least thirty other engineering specialties including; automotive, aerospace, architectural, acoustical, bio-engineering, ceramic, chemical, computer, electrical, environmental, geological, geothermal, heating, ventilating and air conditioning and refrigeration, industrial, manufacturing, materials, metallurgy, minerals and mining, naval, nuclear, ocean, optical, petroleum, plant, plastics, robotics and automated
systems, safety, software, and transportation engineering. It must be noted that this list is not entirely inclusive of all engineering branches. It should also be noted that within each of these specialties there are an even greater variety of sub-categories, specialties and expertise. Consequently, when talking about engineering it is important to have a sense of which fields of engineering are being addressed as well as the science and math background required in that field.

In addition to discovering how encompassing the field of engineering is, visits to these companies helped to put some perspective into the scale to which the engineering process is applied and carried out. For example, I visited with Mike Rogers, a 43-year old mechanical engineer turned medical imaging specialist at Eastman Kodak’s Building 214. On entering this facility I had to wait for my host at a secured entry. Building 214 is essentially a warehouse facility in which several hundred engineers, tech people and production workers go about the process of developing a variety of product ideas. This building houses an endless maze of cubicles, a manufacturing area and a multitude of product testing rooms.

Rogers has been one of the team leaders involved with the development and now improvement of Kodak’s version of the digital radiography machine (digital x-ray). This product was initiated approximately ten years ago in response to the advancements being made in digital imaging technology. Members from marketing, research and development, the engineering disciplines and manufacturing were consulted for input into the viability of this problem and enough potential advantage was felt to exist that the project was taken on. A tremendous amount of energy and resources have been invested into the design and development of this $150,000 device. This product has now been on the market for three years and is being used in hospitals nationally and internationally.
An engineered product does not require the resources of an industrial giant such as Kodak, however. Georgena Terry is an entrepreneur in her early-fifties who began her career as a mechanical engineer and executive at Xerox. Terry is an avid bicyclist who recognized a number of years ago that the bicycles she had been riding were not designed with female anatomy and comfort in mind. In the early 1980's Terry took some welding and metallurgy classes and began experimenting and testing bike designs by disassembling and re-welding Schwinn bicycle frames into more comfortable, ergonomically correct configurations. Friends encouraged Terry to build bikes for them as well and in 1985, realizing a vast potential market, Terry left Xerox to create Terry Precision Bicycles. At first the manufacturing, advertising and distributing of these bicycles was done entirely out of the basement of her home. Today Terry works out of rented space in a relatively small building in Macedon. She no longer manufactures the bicycles herself but hires this process out instead. Precision Bicycles has approximately twenty employees who are responsible for a variety of different tasks. Terry, the only engineer on staff continues to design internationally respected bicycles and bike accessories, such as seats, for the female bicyclist. Her bicycle prices range from $350 to $2,000 with revenues for her products having quadrupled from 1.5 million in 1997 to 6 million in 2000 and $8 million plus this past year. Terry Precision Bicycles was recently included in the Democrat & Chronicle's list of the top 100 companies in the Rochester area for 2001.

These are two very different engineering environments in terms of size and scale, resource availability and atmosphere, but both share the engineering design process as a common element.
The engineering/design process

While the scale and scope of engineering can vary extensively from product to product or business to business, there are some practices that are common to all engineering operations. To begin, the goal of engineering is to design solutions to problems that will benefit people in some way. These solutions usually come in the form of some physical or conceptual product.

In each instance, the representative with whom I spoke was asked about the process that engineers and designers go through in order to develop a final solution. It was found that while there was not a specific, across-the-board answer, there was a general theme common to each.

I asked Bob Cody, a civil engineer and project manager at Sear-Brown Associates about the problem solving process that he is required to use at his company. Cody hesitated before answering that he guessed his company probably had a formal model but that he was not certain what it was. Cody offered instead that the engineering design process is only a general outline of the steps to follow in order to give some direction to solving a problem. He stated that there are a variety of combinations of steps or procedures that have been used successfully to solve different problems. He emphasized that each problem is going to be unique to some extent. Outside influences such as governmental regulations and policies, client needs and desires, environmental conditions and sensitivities and personal background knowledge and prior experiences with similar types of problems will have some influence on how to go about solving it. After having given the process question some extended consideration, Cody e-mailed me an eleven step overview of the engineering problem solving process (appendix a) that he most often goes through before one of his road or bridge projects receives final approval from both the Department of Transportation and/or any local political involvement.
The response from other engineers that I spoke with tended to reflect that of Cody: the design/problem solving process varies from project to project and is always affected by any number of unique circumstances. Most, however, cited a six or seven step process that provides a general overview or guideline. One of the Engineering Design Process models shared looks like this:

1. **Define the problem.** This stage involves identifying what the real problem, task or activity is that has to be solved. It is essential to have a thorough grasp of the problem at the beginning of the process or time, energy and money may be wasted by moving on. This stage also includes identifying the requirements that would have to be met and the constraints that may be placed on the solution.

2. **Brainstorming.** At this stage the problem is analyzed and preliminary ideas and solutions are developed. The problem may be broken down with questions such as is the problem fully understood? (if not, return to step 1). Is more information needed? Has a problem similar to this been solved in the past? Are there any well-known techniques available to help solve this problem? Can it be solved using experiments, mathematical models, simulations or something other?

3. **Evaluation of the solutions.** This stage involves looking critically at each of the initial ideas to determine whether they are reasonable and will meet the design criteria. These ideas are then refined and reworked until it is clear that the proposed solution will work and that it is physically practical. If the answer is yes, then the project moves on to the next stage.

4. **Make and test a model.** At this stage of the process, detailed technical drawings, prototypes, and scaled models are produced. Model performance tests and user
feedback are also implemented during this stage. These elements provide further opportunity to analyze and refine the solution. Questions to consider are: can it be improved? Can it be manufactured? Which materials will work best? Will it be safe? What impact will it have on the environment? Can it be simplified? What costs are anticipated? These, and other questions need to be considered and definitively answered before continuing with the process.

5. **Modify and improve design.** At this point the results of the preceding stage are again evaluated with a similar round of questioning intended to reach an optimal solution to the problem. The strong and weak points are weighed, and the decision is made to either accept this solution and go on to the next stage or reject it and return to the design process loop. Models, prototypes, and simulations are evaluated for their performance and a determination is made whether elements still need correcting or whether the design solution can now be draw up and put into production.

6. **Communicate the final design.** At this last stage the final technical drawings, documentation and manuals are produced. This technical information gets sent to those responsible for producing or manufacturing the designed product. It may be that an individual or an automated production system is responsible for creating the final product.

**The Optimal Result**

While engineering/design process models may vary with regard to terminology or number of steps, the objective is ultimately the same, to design a solution to a given problem that produces an optimized result.
According to Rogers of Kodak, optimization is a method for calculating the best possible utilization of resources. Depending on the project, these resources might include people, time, processes, equipment, raw materials, supplies, capacity, capital and/or other commodities. Optimization methods are intended to help reduce costs while increasing productivity, and profitability by improving the speed and quality of decision-making.

Cody of Sear-Brown shared an example of the potential complexity in reaching an optimal solution. In this particular case, the problem called for "determining the characteristics of the most cost-effective transit system possible consistent with adequate safety, reliability and comfort while using as little land, material and energy as possible." The table referenced showed me included a list of 45 trade-off issues that would possibly be considered in designing this new transit system (appendix B). Each trade-off issue in this example was given two alternative options. Given this scenario, this problem results in a mathematical possibility of \(2^{45} = 35,200,000,000,000\) combinations. That is a tremendous number of design considerations.

Cody agreed that it is difficult and occasionally tedious work but he emphasized that each alternative must be studied and analyzed thoroughly to avoid risking a design with potentially fatal flaws. He concluded with the observation that processing an optimal design solution on paper is much less expensive than correcting problems after a project has been built.

**Precision and Accuracy**

Some design problems by their very nature are far more complicated and complex than others and require very exact interaction of parts. The necessity of getting solutions correct on paper was one of the messages conveyed by John Mullen the president of OptiPro, a lens and parts manufacturer and distributor of high precision machinery. Mullen's company produces products for the medical and space industry that require very exact measurements. OptiPro’s
lens-producing machinery is capable of creating lenses accurate to within a half wavelength of
the given specification.

Mullen made the point that while his machinery was capable of producing extremely
accurate results, the end product is only as good as the design. He noted the case of the Hubble
space telescope. This billion plus dollar project was discovered to have a flaw in its mirror. This
discovery was made only after the project had been launched into outer space. In reviewing their
calculations, it was realized that the shape of the mirror was off by about 1/50th the width of a
human hair. This “minor” flaw however, was enough to prevent a clear image to be gathered by
the telescope and endangered a variety of projects that depended on the telescope working
properly. This embarrassing billion-dollar blunder was ultimately corrected by further
engineering and is now producing fabulous results, but at a cost much higher than initially
projected.

The precision designed into an object will very based on the function of the product. For
example, the precision designed into the toy that comes with a happy meal will require far less
precision than say a Rolex watch. The opportunity to walk through the production facilities at
OptiPro, Hoercher Tool and Die and G.W. Lisk helped to put this concept into perspective.
G.W. Lisk is a worldwide leader in the design and manufactures of solenoids, solenoid valves
and flame arrestors. Their products are used in the automotive, aerospace and nautical industries
as well as for medical and military applications. Roy Spring, an engineer and public relations
specialist with the company commented that most designs call for minimum tolerances
measuring in the ten thousandths of an inch. He also clarified that precision relates to the
composition of the material as well. All of the products that are manufactured at Lisk are custom
designed for their clients. For many of these applications the solenoid was designed and
manufactured to perform successfully under extreme conditions. He displayed products designed to function normally deep in the ocean, and into outer space; he also had devices that would withstand inferno conditions and explosions. If these devices should fail to perform under any of these conditions, the results could be potentially disastrous.

Some of the machinists that I spoke with at Hoercher Tool and Die suggested that it is important for students to know how to read an orthographic drawing and to be able to measure using different measuring devices such as scaled rules, vernier calipers, micrometers etc... If a dimensioned working drawing does not provide any tolerance information, the machinist can assume 0.004” leeway in producing the product. Machinist at Hoercher Tool & Die commented that they referred to this allowance as being pretty "sloppy" (note: a sheet of paper and a human hair both measure around 0.003”). At each of the production facilities that I visited there was evidence of manufactured parts that failed to meet quality control standards. Bins were filled with parts that appeared perfectly fine to me but were headed for recycling because they did not pass a quality control check. The product may have been dumped because it failed to meet any number of the constraints placed on it. These may have included misplaced features, over or undersized parts, material failure, etc... At each facility there was an odd assortment of measuring and testing devices that I had never seen before. These tools are used to guarantee that the final machined product meets the conditions and standards that were engineered into it before it was sent to the customer.

The Kiss Philosophy

There is a tendency for some designers to take the precision element to unnecessarily limits simply because the technology and ability are there to do so. During my visit to Kodak, Mike Rogers demonstrated two solutions to the same digital x-ray problem. He pointed out that while
the two machines had many similar conceptual and physical features, one of them was much superior to the other in its design. Mike commented that there is a tendency for some designers to over-engineer a solution simply because the technology and knowledge exists to do so. Mike talked about the KISS (keep it simple stupid) philosophy of design. Essentially, this approach to problem solving calls for reaching a solution as efficiently and cost effectively as possible. To demonstrate this point he showed me the two x-ray units placed side by side. He explained that one element of the problem required designing a way to move the digital recording cassette into position to shoot the image and then return it to its original entry point. The design for the first unit called for a loading mechanism that gripped and revolved the cassette before guiding it across a vertical track and into its proper position. This solution worked but entailed a series of complicated pinching and pivoting motions to perform the task. This design also required the fabrication of a variety of customized parts and called for some expensive electronics components. Mike noted that this design required 40 moving parts and cost a bit over $4,000. He then demonstrated the second design solution, which performed the same function but required only ten moving parts at a total cost of $40. He commented that when you are talking about a machine that sells for over one hundred fifty thousand dollars in a very competitive market it is crucial to design in the most cost-effective manner while still producing a quality product. Mike pointed out that the first design broke a couple of designing guidelines. A good design attempts to minimize the number of moving parts. He commented that its easy for some engineers to get caught up in complex designs and lose sight of the economic implications of what they have designed. He also mentioned that a good design will use commercially available components whenever practical. Keep it simple, optimize results, and solve the problem.
Design with people in mind.

Another key consideration when designing for optimal results must be the question of whom the likely user is going to be. The designer must be mindful of the physical, physiological, emotional, and mental limits and capabilities of the end user. Consideration must be given to the conditions under which the product may be used. Ultimately, there should be a comfortable fit between the user and the product. It was a lack of fit that spurred Georgena Terry to begin innovating new frame designs. She got into her specialty because she felt (literally) the need to correct a flawed design. Bicycles that were being sold as women’s bikes, were men’s bikes without the cross bar. Terry was able to innovate a frame configuration and seat design that proved to be much more comfortable for women. Sales of her bicycles indicate that there is considerable appreciation for good fit in product design.

According to Shelly Wasala, a consultant at Ergonomics Solutions, consumers are becoming much more educated and aware when selecting products, especially ones that they will be using for extended periods of time. She demonstrated some of their product lines by seating me in an ergonomically designed adjustable chair situated in front of a height adjustable, tilting computer workstation. She placed an adjustable footrest under my feet and suggested that I try the computer, which was equipped with a split keyboard; comfortable wrist support made of a conforming foam material, an ergonomically designed mouse and controlled lighting. It was a noticeably different feeling from what I’ve become accustomed to. Her point was that we tend to place a great deal of undue strain on our bodies and ergonomic designs strive to create products that work in harmony with our bodies. In the past, you were limited as a consumer in the choices you had, today ergonomics is a major selling point of many products. This concept
of "fit" and "user friendly" or ergonomics has become an increasingly important element in determining the marketing success or failure of a given design.

Terry Precision and Ergonomic Solutions are excellent examples of businesses that have founded themselves on designing products that provide good fit with its user. It should be noted that the concept of fit extends to any design in which the user comes in direct contact with the product. Most of the people that I spoke with made some mention of a very competitive marketplace and the importance of designing products that are safe, reliable, durable, reasonably priced, aesthetically pleasing, comfortable, and easy to use.

Communication is key

Of all of the practices that were common to the companies I visited, good communication surfaced as the element most frequently cited as essential to successful product design. In order to achieve an optimal solution, it is critical to have clear communication throughout the product development cycle. A good example of this occurs at the G.W. Lisk, Inc. This company is unique in that all of the products manufactured in their facility are custom designed to meet the needs and specifications of clients from all over the world. Roy Spring, spoke about the need and importance of working closely with the customer in order to produce exactly what they want. When a client approaches the Lisk Company they are put in contact with designers who work thoroughly to identify the surrounding nature of the problem and the needs of the customer. In their case, customers may come from virtually any country or any field of manufacturing. Spring commented that it is not always an easy task to communicate the various needs especially when language and cultural barriers are added to the equation. He noted that in the engineering field technical drawings and sketches can often communicate more clearly than the spoken or written word. He described working orthographic and isometric drawings as a form of universal
language. Mike Rogers cautioned that while drawings that are done correctly communicate effectively, it is critical to know who the audience is. He made the point that people in marketing, sales or even the client may have little understanding of many technically detailed working drawings. When presenting to such groups it often makes clearer sense to use renderings or pictorial drawings of the product to convey an idea or concept. He emphasized the importance of communicating in terms that the audience will understand.

Rogers and the other engineers also commented on the collaborative nature and necessity of the engineering design process. Since it is virtually impossible to possess all of the necessary expertise necessary to reach an optimal solution working teams of engineers are often assigned to various problems. Rogers estimated that he has worked with hundreds of engineers and tech people while developing Kodak's digital radiography machine. This team approach can prove to be very productive or frustrating depending on the composition of abilities and personalities. In order for a solution to be reached in an efficient manner these team members must be in regular effective communication with each other. He spoke about the importance of being able to seek advice from those better qualified than yourself and being willing to listen to ideas that may not correspond with yours. As mentioned earlier there are many specialties in the engineering field and often a variety of those specialties are called upon to solve a complex problem.

In addition to maintaining tight contact with design team members there needs to be an ongoing dialogue with the client or in the case at Kodak, potential client. G.W Lisk, Precision Packaging, OptiPro, Hoercher and Sear-Brown all put heavy emphasis on making certain that important decisions included input from the client. They will, after all, be the ones using the product and paying the bill. Norm Fenton, a packaging designer at Premier Packaging commented that it is their responsibility to guarantee that the client is pleased when a project is
completed. He added that it is part of their job to try to educate the client and guide them away from unfeasible design proposals even if it means losing a sale.

Dennis O'Dey, another engineer at Kodak who is part of the radiography project informed me that throughout the entire designing process they have been consulting with radiologists and medical techs in order to gather as much information about their needs and wants as possible. This data was implemented into the final product to the extent that was feasible. He commented that even though the product has been out on the market for over three years, they continue to monitor their product by maintaining regular communications with medical personnel who are using the Kodak machine. This, he said, has allowed them correct performance flaws and to implement design improvements into the next generation of digital radiography machines.

Finally, companies must have some method of communicating to potential customers that they have a product or service worth purchasing. This communication has traditionally been conducted in trade publications or other specialized publications. Recently, however, more and more companies are attempting to establish a web presence in order to communicate their product and capabilities to the consumer market. Terry Precision, for example has shifted emphasis from retail to catalogue and Internet sales. She made the observation that you need to be able to present your product in such a way that people will understand what you are selling and how it is of benefit to them. She went on to state that you may have created the best product in the world but if you fail to communicate that on the first impression people likely won't be interested in buying from you.

The state of the engineering profession

In speaking with people in the profession there is a general concern that interest in this field is declining. According to the Rochester Engineer, a publication put out by the Rochester
Engineering Society, surveys reveal that many students at the college level find engineering degree courses boring. This is especially true of the theory courses typically found in the first few years of many engineering programs. Conversely, the perception of people in industry is that engineering graduates are not coming into the work place very well prepared. Efforts are being made locally to educate the public by exposing young people to the engineering process and profession. For example, Engineering Week was held at the Rochester Museum and Science Center in February. This was a hands-on exhibition designed to demonstrate that engineering can be fun and exciting. Similarly, Rochester Institute of Technology and the University of Rochester have offered inexpensive summer camps to lure girls who may be curious or interested in pursuing engineering as a profession.

Many of the engineers and production people that I spoke with commented on the importance of having taken some sort of materials processing or design class in high school. They indicated that it made them at least somewhat aware of the characteristics and capabilities of machinery and materials. Georgena Terry remembered having always enjoyed taking things apart to see how they worked. Her feeling is that it would be helpful for students to have some similar opportunity. She commented that it is a whole lot easier for a student to understand theoretical engineering concepts when he can apply it to a project in hand.
Discussion

When I began this investigation I was pretty certain that I would discover some new insights into the engineering design process that could be used in the classroom. What I had not anticipated was the depth and immediate utility of these insights in my Design and Drawing course content. One of the major benefits that resulted from the interviews, tours, and conversations was that the product design process was clarified and demystified, at least to some degree. Obviously, it takes considerable time and experience to develop the skills necessary to work in this profession but even these brief glimpses into the process have enabled me to teach about the process with more certainty. It has also made it much easier to bring relevance to the tasks that students are being asked to perform. Being able to explain with concrete examples the relationship between what they are being taught and what takes place in the engineering and design fields has added additional credibility to the content of the course.

Simultaneously with this newfound understanding is the recognition that there is much that I do not understand. Walking through the different production facilities and witnessing the variety of technology and innovation left me awe-inspired and overwhelmed at times. The realization of how little I know about the various engineering and production processes left me questioning how I could convey all of this to my students. The answer is that I can’t. I have to keep in mind that I am teaching in a program with limited resources to a clientele with limited experiential background. I have to remember that this is an introductory course taught primarily to freshman and sophomores, not to upper level engineering students. Consequently, my focus should be on teaching the fundamental concepts of design and drawing and problem solving, while placing emphasis on the professional expectations that these students may be called on to use some day.
For example, one of the problem solving activities that I introduced to my students involved the design of a desktop organizer (appendix c). This problem was set up as though each student was part of a design team working for the same company. Therefore they all had a common goal of producing a design that would answer the problem optimally and become a big seller for the company. The problem called for students to be arbitrarily assigned to groups to brainstorm the various interests and wants of a particular age group. Each age category then presented their findings to the entire design team who contributed further comments for consideration. Students made recommendations on such things as safety, aesthetics, materials, and ergonomics, while engaging each other in critical analysis of their design proposals. At the conclusion of this stage, we worked together to clarify the problem and constraints and they began the work of designing their product. Each designer was responsible for evidence of having worked through the design process including an isometric rendering of their final design, and a written rationale for why they designed their product the way they did. They were also highly encouraged to measure the elements that they were intending to place in their design. This included such items as paper clips, pens and pencils, photographs, CD cases, etc... At the conclusion of this design problem, each student used the overhead projection system to present their final solution to their peers for critiquing. This included a dimensioned working drawing as well as a 3 dimensional isometric drawing with parts list. This was the first time that we had done this sort of thing and overall students did very well. Getting them into the mindset that we were all working for the same company and that this process was not intended to criticize their work but rather to provide an opportunity to gather more insight for consideration seemed to help calm some of them when presenting.
We are currently working on a problem solving activity that was set up to emphasize the competitive nature of product design and importance of being the first company to get your product to market place. This problem has also proved to be a good opportunity to demonstrate the KISS philosophy of design. This task was first given to the students as an individual problem in which they had to brainstorm a minimum of ten ideas. They were then randomly paired with two other students. Many of them whined about the problem being too hard or even “impossible” and wanting to get immediately into groups. The idea however, was that the expectation is that everyone should be coming to the design table with ideas to contribute and that nobody should be coat tailing on the work of others. It was hoped that they would have an opportunity to work collaboratively and experience some of the advantages and problems that go along with working in teams. We will discuss the dynamics of how each group came to its final design solution after their product is finally demonstrated. Once their team decides on a design they are to draw it up and patent it. This problem has also created the opportunity to discuss such elements as product reliability, calibration, math and science.

When I first began this investigation I was not quite sure whether professionals would be willing to give up time in their day to spend time with an outsider. What I found in every case was individuals who were generous, hospitable, helpful and insightful. My impression was that these are people who are passionate about what they do and are very willing to share and promote their profession. I have received offers from some to come speak with my students. I have also received offers for my students to come tour their facilities. These individuals were also very generous in providing me with product samples to bring back to the classroom. Once again these are resources that add an element of authenticity and relevance to the class content. The recognition that there is support in local industry is comforting to know.
Probably the greatest benefit that evolved from this research project was the confirmation that I have been doing a credible job presenting the engineering and design process. There was always a concern that I may be teaching my students content that was irrelevant or even incorrect. In speaking with these professions I was reassured that I am going about my teaching approach in an effective manner. Some of the elements that were listed above, I had already been teaching however, there were new discoveries and realizations that I intend to incorporate into my classes in the future and not just my Design and Drawing classes. My belief is that elements of these recent findings hold some relevance for all of the courses that I teach. I think that we can attain a fine balance between establishing and promoting a professional environment and attitude while still recognizing that we are young students in a high school technology class.
Appendix

Appendix a:

Having considered the task of assisting you in defining what an engineer’s “typical” “design process” is, I thought I’d summarize the process that I typically go through on any one of my projects. (In other words, I wasn’t successful at finding that magical reference here at the office that would give the answers you may be looking for.)

Keep in mind that depending on the particular client, the process may be altered a bit. The fundamentals are often the same. But, the differences are usually related to the level of detailed analysis and/or consideration of outside influences and decision-makers.

I’ll use the most stringent example I can find...working for the New York State Department of Transportation (DOT) on a common roadway reconstruction/rehabilitation project.

Let’s say the DOT has asked me to improve a section of Rt 96 from Bushnell’s Basin to Victor. First off, how did the DOT know enough to improve this particular roadway, especially at this time? The answer may be as simple as some local politician flexing his influence over the state agency (DOT) and/or responding to his constituent’s requests/concerns/demands about some “perceived” troublesome aspect of the road...like, “I can never turn left out of Powder Mill Park at 5pm weekdays” Or, “It always takes me 20 minutes to go from BB to Eastview Mall”. Or this one (one of my favorites), “The roadway is too noisy. Can you do something about getting traffic off of it?”

More times than not however, there is an obvious legitimate reason. Examples of this abound (pavement is falling apart, storm sewers often back up and flood the roadway, excessive traffic congestion at all times of the day, frequent accidents occur at the same location, fatal accidents have occurred, too many pedestrians and/or bikes...the list goes on).

OK, so now I have a project. But, what are the real problems that need to be solved? And, more apropos, how do I decide what to do?

There are 2 basic elements of the design process that I’m most familiar with, engineering and social/environmental/economic considerations. The latter is a reflection of the State Environmental Quality Review Act (SEQRA), a thorn in the side of any single-minded engineer. In the past, there was only one solution to all problems, and that was the engineering solution. SEQRA requires the consideration and involvement of many non-engineering principles, including input from common citizens, the general public and other potential environmental consequences.

In a nutshell, the design process goes like this:

1. Review existing conditions and identify and/or verify problem areas (engineering and social/env/economic considerations)
2. Project future conditions if nothing were done today. (How bad will things get?)
3. Develop a list of needs along the corridor that could be addressed by this project. Prioritize those needs (safety is usually first, followed by things like fixing congestion problems, fixing deteriorated road surfaces, improving stormwater drainage, develop a cheap solution...)  
4. Develop a variety of alternatives that address the needs. (Note: These alternatives will address each need on varying levels.)  
5. Summarize the pros and cons to those alternatives  
6. Make an "engineering recommendation on which alternative is best (i.e. which alternative best addresses the prioritized needs list)  
7. Allow outside reviewers/agencies and (at time) the general public to weigh in on their preferences  
8. Take in all input and ultimately decide on a single alternative to progress to construction  
9. Develop construction plans and documents  
10. Build it

So how does this apply to the "design process"? Or, better yet, what are the key elements (steps) of the design process (as I see it anyway)?

1. Determine what is being designed. Why? Is there a problem or does someone just want to improve something, in anticipation of possible future problems? Who will have authority over the final outcome?  
2. Verify existing conditions  
3. Determine existing "minimum" standards and design constraints  
4. Develop a prioritized list of objectives (somewhat general, but lofty none-the-less...i.e. improve safety, improve motorist satisfaction with the roadway, address future traffic congestion, minimize adverse economic consequences of the project (don’t put anyone out of business)...)  
5. Determine what future conditions may be, if nothing were done today. This is usually the toughest part of the process...definitely crystal ball stuff. Remember that you can’t just build for today’s needs without risking the likelihood of an obsolete solution the day you complete construction.  
6. Based on the objectives listed, coupled with a review of existing and projected problems and conditions, list all of the needs. That would be a specific/detailed list of all the problems identified to include substandard geometric features, poor infrastructure conditions and anticipated problems.  
7. Develop a series of alternatives that address the needs identified  
8. Identify the pros and cons of each alternative. In other words, how does each alternative address the aforementioned project objectives. If safety is the most important objective, the alt that does that may be the best. Unfortunately, it’s never that simple. Most of the time, they all address safety, but they also address the other objectives as well.  
9. As objectively as possible, select the single alternative that provides the best combination of improvements. That would be my “engineering” recommendation.  
10. How ‘bout that SEQRA element I mentioned before? Even though there is merit to that requirement, it unfortunately adds the subjective decision-making part to the design process. Will the visual impacts of the project be too great? Are we going to effect a historic site?
Will noise levels increase? Will we have to displace a private home owner, or his business, and god help us, is he an influential politician?

11. The final say (decision) often comes from the senior-most DOT official (with plenty of input from politicians who have an influence over the well-being of that senior-most official). We call this "Design Approval"...or the point at which final design of the alternative can commence.

Without getting into too much detail about the stuff I do every day, that pretty much summarizes the design process that I go through.

I know it's not a flow-chart, or a list of "buzz-words". But, if you attempt to break it down, you should be able to find a common thread that can be applied to any design process.

I hope I haven't just wasted your time either. Good luck, and call me if I can do anything else...I mean it.

Bob
Appendix B:

Table 1. Tradeoffs in the Design of a New Transit System

**Objective:** Determine the characteristics of the most cost-effective transit system possible consistent with adequate safety, reliability and comfort while using as little land, material and energy as possible. Proceed by identifying and analyzing each alternative in each trade-off issue. A brief summary of the results of such analysis is as follows. The optimum selections are in bold italics. The full reasoning is provided in more detailed documents.

1. **Travel Characteristics:** multi-stop or **Nonstop**
2. **Way Characteristics:** mixed traffic or **Exclusive**
3. **Vehicles:** may run on streets (Dual Mode) or **captive to guideway**
4. **Stations:** on-line or **off-line**
5. **Intersections:** people transfer or **vehicles transfer**
6. **Usual Guideway Level:** at grade, below grade or **above grade**
7. **Vehicle Capacity:** large, medium or **smallest practical (one bench seat)**
8. **Passenger accommodations:** may stand or **seated only**
9. **Service:** scheduled or **on demand**
10. **Ride:** with strangers or **only with others by choice or alone**
11. **Fare:** per person or **per vehicle**
12. **Vehicle control:** manual or **automatic**
13. **Position of vehicles:** hanging, at side of guideway, or **supported**
14. **Moving switch element:** at wayside or **on vehicle**
15. **Axis of switch rotation:** vertical, transverse or **longitudinal**
16. **Switch stability:** neutral or ** bistable**
17. **Guideway Configuration:** straddle or **trench**
18. **Guideway Configuration:** Suspension: air cushions, magnetic, or **wheels**
19. **Propulsion:** ICE, cable, air or **electric**
20. **Propulsion (electric):** rotary motors or **linear motors**
21. **Motor type:** two sided or **single sided**
22. **Motor position:** in track, **on board,** or both
23. **Drive:** fixed frequency or **variable frequency**
24. **Control:** all at central or **dispersed**
25. **Drive train:** single or **dual**
26. **Reaction rails:** vertical or **horizontal**
27. **Tire material:** steel, solid or **pneumatic**
28. **Tire surface:** rough or **smooth**
29. **Wheels:** steerable or **fixed**
30. **Guideway shape:** wider than vehicle or **narrower than vehicle**
31. **Guideway material:** concrete, aluminum, composite or **steel**
32. **Guideway design:** plate or **truss**
33. **Guideway joints:** at posts or **away from posts**
34. **Covers:** no or **yes**
35. **Guideway attachment:** simply supported or **clamped**
36. **Power:** primary only or **with backup**
37. **Power location:** on-board battery or **wayside battery**
38. **Guideway directionality:** two-way or **one-way**
39. **Running surfaces:** fixed or **adjustable**
40. **Interchanges:** X or **Y**
41. **Network control:** synchronous, quasisynchronous, or **asynchronous**
42. **Vehicle control:** car following or **point following**
43. **Headway law:** fixed time, fixed space, **fixed safety factor**
44. **Control type:** analog or **digital**
45. **Vehicle sensing:** line of sight or **through guideway**

Number of combinations if only two in each: $2^{45} = 35,200,000,000,000.$
Appendix c:

the Organize This co.
PRODUCTS FOR THE HOME & OFFICE

To: All Designers
From: Product Development
Date: 2/07/02
Re. Desktop organizer design

Problem: develop a workspace organizer for young people.

Specifics: design must be stylish, yet functional and appeal to growing youth market. Target will focus on 4 different age categories; 4 to 7 years, 8 to 12 years, 13 to 16 years and 17 to 20 years.

Your design must include:

- Compartment(s) for common stuff (white out, post its, note pads...)
- Container for writing utensils (pens, pencils, markers, crayons, fat markers, paint brushes...)
- Holder for a fastening devices (paper clips, staplers, rubber bands, tacks, glue, glue stick)
- File system (papers, index cards, jewel cases, floppy disks,
- Picture holder (based on common size photographs)
- Other...specific to age group

Considerations: target group, ergonomics (sizes and positions of "holders"), safety, material(s), style, color, balance, proportion...

Constraints:

- Base may not exceed an overall dimension of 10" x 14"
- Materials may include wood, Plexiglas, sheet metal, molded poly
- You will have ______ workdays to finalize your design
- Presentations will be given on ________

To turn in:

- Parts drawing of the base and all accessories (this includes a pen and/or pencil, paperclip, CD,
- Working drawing of the base and accessories
- Assembly drawing of the final product
- Design write-up reflecting on target market and rationale.
Bibliography


