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# Project ProBASE: Design for Pre-Engineering Education

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## Background and Overview

Engineering education is confronting some significant pipeline challenges at the K-12 level in preparing students for university engineering education programs. These problems include a lack of engineering career awareness as part of the K-12 curricula, a disproportionate underrepresentation of females and minorities, a lack of a coherent vision of how students can best be prepared for and oriented to post-secondary engineering opportunities, and a lack of dialog between collegiate level engineering educators and K-12 educators regarding preparation for and opportunities in engineering.

The root causes of these problems are multifaceted and include political, curricular, and communication issues. At one level, the problem has to do with a lack of a comprehensive vision for how secondary level pre-engineering education should be focused, configured and delivered. The traditional approach has been to require strong backgrounds in mathematics and the sciences along with high college entrance examination scores. While this screening process may indeed identify students capable of succeeding in engineering education at the university level, it typically fails to provide students with any concept of what it is that engineers actually do on a daily basis. This approach also excludes essential engineering concepts and experiences such as design, technological problem solving, systems analysis and the tradeoffs associated with technological proliferation. As a result, many students enter post secondary engineering programs with a limited understanding of the profession and are not typically prepared with the knowledge and skills needed to succeed in engineering education.

A number of projects and initiatives are currently underway, which collectively are beginning to address these problems. Some of these initiatives include Project Lead the Way (PLTW)[1], NSF funded curriculum pre-engineering projects (engineering and education directorates), NASA sponsored educational initiatives, and more. A recent issue of the ASEE Prism identified and described several models, including a state-mandated pre-engineering requirement (Massachusetts), an entrepreneurial, private industry-based model (Texas), and an engineering outreach program, housed at the University of Colorado.[2] Additionally, the National Academy of Engineering's Committee on Engineering Education is in the initial stages of pursuing funding for a pre-engineering project that would conduct research to identify and classify national, regional, and local initiatives and projects at the K-12 level, which are contributing to the preparation for engineering education at the collegiate level. The study would also be designed to coalesce a vision for K-12 pre-engineering education and culminate in a set of recommended activities, policy changes and initiatives.

An additional project related to this effort is Project ProBASE, housed in Illinois State University's Department of Technology. Project ProBASE (a National Science Foundation funded project) is developing standards-based problem solving curriculum materials for advanced level high school technology education. A central thrust of this project is to provide a comprehensive base for engineering education at the post-secondary level including engineering career awareness, applied mathematics and science concepts, and technological problem solving strategies. The curriculum materials being developed are based on enduring understandings derived from the core concepts identified in *Standards for Technological Literacy: Content for the Study of Technology*[3], a comprehensive content framework for technology education. These standards were developed in close collaboration with the National Academy of Engineering and were formally approved by a review committee at the National Research Council, chaired by Dr. William Wulf, President of the NAE.

**Philosophy and Approach**

At this juncture, it is important to provide a brief background of technology education, since that academic area represents the broad academic and philosophical content for the ProBASE project. Over most of the past two decades, technology education has experienced a major paradigm shift from its industrial arts history. "Shop" classes for career bound academic underachievers has given way to technological literacy for all students and advanced level technological education for students pursuing careers in areas such as engineering, architecture, and advanced level technical positions. The historical focus on industry as the base of content has given way to a broader range of content including areas such as agricultural, medical, and bio-related technologies. The focus has also expanded to embrace a comprehensive set of issues including the complex interrelationships between technology and society, politics, economics and the environment. *The Standards for Technological Literacy*[4] were specifically designed to provide a comprehensive and structured conceptual framework for the study of technology. While these were developed by the International Technology Education Association (ITEA), aspects of the *Standards* are clearly applicable to other academic disciplines (i.e., history, science, mathematics, social studies, etc.).

Project ProBASE is grounded in constructivist educational philosophy and has been informed by the work of Grant Wiggins and Jay McTighe in their book, *Understanding by Design*[5]. The core of this approach is a concept called "backward design" where "one starts with the end—the desired results (goals or standards)—and then derives the curriculum from the evidence of learning (performances) called for by the standards and the teaching needed to equip students to perform" The initial step in the process involves the identification of a set of "enduring understandings." These are the core concepts, the large, robust ideas that are considered essential to a discipline. With ProBASE, the project team focused considerable time and energy during the initial stages of the project on an analysis of the Standards, to "boil" them down to the core essentials for a solid pre-engineering curriculum. The results of this process will be presented later in the paper.

Once the enduring understandings are identified and clarified, the curriculum development process then moves directly to assessment, where curriculum developers determine the types of evidence indicating that students have internalized the enduring understandings. The assessment should be authentic, contextualized, and clearly connected to the enduring understandings. Only after the assessment issues have been clarified, is it then appropriate to move into the process of designing lessons and developing activities. While the backward design process makes sense from a curriculum design process, the reality is that many teachers (particularly in the applied areas) tend to concentrate on developing rich and engaging learning activities prior to and, in some cases, in lieu of clearly defined goals.

**Project ProBASE — Curriculum Development Process**

The Project ProBASE curriculum consists of a set of eight, 9-week modules that are being developed for delivery at the 11th and 12th grade levels. The modules are designed to use engaging design and problem-solving activities to teach the enduring concepts identified from the *Standards*. The focus of each curriculum module is directly aligned with the context standards in the *Standards for Technological Literacy*. These are: agricultural and biotechnology; information and communication; entertainment and recreation; energy and power; transportation; medicine; construction; and manufacturing.

The design of each module consists of a preliminary "hook" activity to generate student interest and to focus the content. Next, a primary challenge is presented to the students. This challenge is designed to cause students to synthesize and transfer learning in order to develop a solution to a major technological problem. Each primary challenge is also specifically designed to address the enduring understandings and assessment protocols for each module. When the primary problems are first presented to students, it will be made clear that the solutions will likely be multiple, complex, and initially beyond their ability to solve. For example, the primary problem for the entertainment and recreation module consists of challenging students to conduct research into extinct musical instruments (including their social significance), to construct a similar instrument, and then collaborate with other student groups to compose a simple score of music. This challenge is designed to engage students with concepts such as historical research, applied physics, materials science, design under constraint, and social-cultural issues.

After introducing the primary challenge, the curriculum is then designed to move students through a series of constructivist-based, learning cycles consisting of four phases. These are exploration (asking questions, gathering materials, conducting preliminary research, etc.), reflection (answering questions, analyzing data, formulating generalizations, etc.), engagement (designing and building, testing ideas, solving problems, etc.), and expansion (generalizing concepts to other contexts, exploring engineering career options, etc.). Each learning cycle activity is specifically selected and designed to (a) cause students to engage with the enduring understandings and (b) collectively, to enable them to transfer their learning to arrive at a solution for the module's primary problem. A flowchart illustrating the ProBASE curriculum development process is presented in Figure 1.

**Enduring Understandings**

The paper began with the assertion that pre-engineering education at the secondary level should be extended beyond advanced level mathematics and science courses, to also include a solid introduction to a comprehensive set of core technological concepts and capabilities. Not only do these technological concepts provide an application arena and rich authentic context for mathematics and science concepts, it needs to be understood that they are fundamental to

**Project ProBASE Curriculum Developmental Flowchart**

**Enduring Understandings** *(What is worthy and requiring of understanding?)*

⇩

**Essential Questions** *(What questions are at the core ideas of technology?)*

⇩

**Module Theme**

| **Module Specific Enduring Understandings** What will students understand because of this module? | **Module Specific Unit Questions** What questions will focus this module? | **Acceptable Evidence** What evidence will show that students understand? | **Primary Challenge** What complex design challenge encompasses all unit questions? | **Learning Cycles** What knowledge and skills are needed to answer the Primary Challenge? | **Summative Module Assessment** What are acceptable solutions to the Challenge? |
|---|---|---|---|---|---|
| 2-3 per module | 10-12 per module | Derived from unit questions | Complex challenge that drive learning cycles. | Multiple, 4-phase learning cycles | Alternate Solutions to the Primary Challenge |

Figure 1. *ProBASE Curriculum Develop Process Flowchart*

understanding technology and engineering. Given that the primary goal of engineering is to design the human made world to address human needs and wants, it is essential that pre-engineering education include an orientation to the fundamental concepts of technological literacy. These concepts should extend beyond the traditional boundaries of engineering (design constraints, functionality, etc.) to broader social, economic, political and environmental issues.

The initial foundational phase of the ProBASE project consisted of identifying the technological concepts deemed to be essential to pre-engineering education. A set of "filters" was used to identify nine enduring understandings for the project. These filters included (a) representing a big idea with enduring value beyond the classroom, (b) residing at the heart of the discipline, (c) requiring uncoverage of abstract and frequently misunderstood ideas, and (d) offering potential for engaging students in learning.[6] As noted above, the primary source for this process was the *Standards for Technological Literacy*[7]. The essential understandings including representative focus questions are presented below in Figure 2.



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*Students will understand:*

1. that technological progression is driven by a number of factors, including individual creativity, product and systems innovation, and human wants and needs.
   *What social, cultural and political pressures lead to technologies? What are the roles of professionals involved in technological adaptation and change?*
2. that technological development for the solution of a problem in one context can spin-off for use in a variety of often unrelated applications.
   *How do technologies migrate from one context to another and what are the implications? What roles do patent and copyright laws play in the dissemination of technological ideas?*
3. that technological change can be positive and/or negative, and can have intended and/or unforeseen social, cultural, environmental, and political consequences.
   *What are some of the unforeseen consequences of technological change throughout history? How can a technology cause both good and harm and how do humans prepare for or respond to these impacts?*
4. how technological systems work, the components of those systems, and how they fit into the larger technological, economic, and social systems.
   *What are the systems and subsystems involved in the various contexts of technology? How do technological systems influence the economy, society, and the environment?*
5. The compelling and controversial issues associated with the acquisition, development, use, and disposal of resources.
   *To what extent have resource issues (acquisition, development, use, and disposal) affected the direction of technological development?*
6. that the complexities of technological design involve tradeoffs among competing constraints and requirements, including engineering, economic, political, social, and environmental considerations.
   *What are design limitations and how do they cause designers/engineers to make changes in new technological products and systems? What are design constraints and how do they affect the development of new technologies?*
7. that technological design is a systematic process used to initiate and refine ideas, solve problems, and maintain products and systems.
   *What design criteria are typically used when developing new technologies (i.e., marketability, safety, usability, reliability, cost, materials, etc.)? How do these influence the final product/system design?*
8. how technological assessment is used to determine the benefits, limitations, and risks associated with existing and proposed technologies.
   *How does a risk/benefit analysis aid the designer in addressing potential harmful effects prior to development? How are ethical considerations, economic considerations, engineering realities, and political forces balanced during technological innovation?*
9. how a variety of technologies are utilized and operated either by typical consumers or by specialists.
   *How is technology used to control devices and systems and provide information to humans?*

Figure 2. *ProBASE Enduring Understandings*

## Concluding Comments

The eight curriculum modules will be disseminated nationally for use primarily in advanced level technology education classes. They are being designed to be incorporated into mathematics and science classes as well. The materials are being designed to embody key elements typically missing in pre-engineering education. These include identified pre-engineering content, rich problem solving and design activities, authentic applications contexts for mathematics and science content and engineering career awareness. In these respects, ProBASE is being designed to serve as a model for advanced high school level pre-engineering education.

A more serious challenge remains. University level engineering educators need to find ways to better collaborate with university and K-12 educators to evolve a vision for pre-engineering, K-12 education. For university engineering educators, this will involve a fundamental rethinking of the skills and knowledge base needed for entrance into engineering programs. At the K-12 level, educators will need to become better informed about the engineering profession. They will also need to find ways to blur the boundaries between academic disciplines, to integrate and apply mathematics, science, and technology concepts. Educational policy issues will also need to be addressed to make it possible to include the study of advanced level technology concepts in pre-college curricula. Project ProBASE represents one effort to move this agenda forward.

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## Biographical Information


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