2006-86: INFORMED DESIGN AS A PRACTICAL PROBLEM SOLVING APPROACH

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Informed Design as a Practical Problem Solving Approach

Abstract

The informed design process was developed as an analytical road map for students to follow when proceeding through an engineering design challenge. This practical problem solving format affords students the ability to refine the constraints and parameters of a design challenge, make the required design decisions and communicate their conclusions graphically via the creation of working industrial drawings, construct working prototypes, perform computational analysis, prepare laboratory reports, and present their conclusions.

In order for educators to provide the requisite skills and abilities that industry requires from graduates of post-secondary engineering technology programs, students must develop the ability to analyze and validate a myriad of considerations during the product design and development phase of a design challenge. This should not be limited to interpreting design requirements and customer specifications, but should also include exposure to applicable codes and standards, intended and unintended modes of usage, hazards of human and non-human origin, ethical concerns, and any internal or external influences that might impact the final product's design. This can all be accomplished by having students follow the principles of the informed design cycle in conjunction with the expectation that students will use scientific and mathematical principles to derive design challenge solutions.

The informed design process provides an excellent opportunity for students to develop time management skills, conduct brainstorming sessions, and foster small group team based dynamics. These skills are required not only of future engineering technologists, but of anyone seeking employment in an ever-changing global community.

Introduction

Design has long been a central theme in engineering and engineering technology curricula. When asked, "what do engineers do?" the typical response is "they solve problems." In that context, design plays a huge role. In recent years, ABET has emphasized the importance of design[1]; and the engineering education community has risen to the challenge of finding creative ways to incorporate design into its programs at all levels.

The incorporation of design into academic programs is not limited, however, to post-secondary engineering and engineering technology. The International Technology Education Association (ITEA), with publication of its landmark *Standards for Technological Literacy (STL)*[2], is encouraging the learning of design for all K-12 students. In fact, *STL* devotes an entire chapter to "Design" that outlines standards for students to develop an understanding of the attributes of design; of engineering design itself; and of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving. The technology education community has, in turn, risen to the challenge of developing effective instructional resources for design at the K-12 level. An impressive example of this is Burghardt and Hacker's middle school textbook, *Technology Education: Learning by Design*[3].

Burghardt and Hacker utilize "The Informed Design Process," illustrated in Figure 1, to introduce students to the engineer's familiar world of problem solving. They point out[4] that most K-12 classroom settings do not challenge students to solve open-ended problems and believe that informed design provides a way to optimize the use of design as a pedagogical strategy.

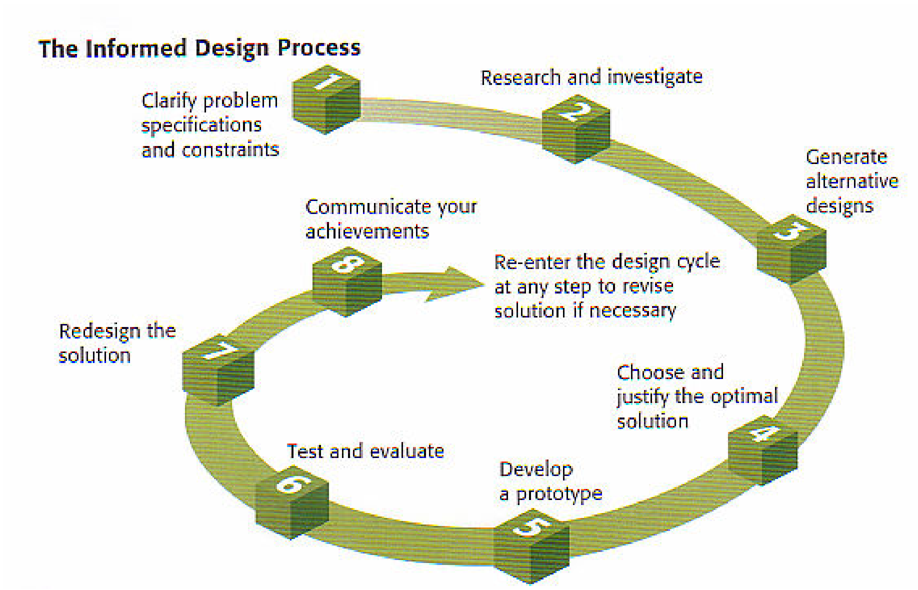


Figure 1. Informed Design Loop.

New York State Professional Development Collaborative

Three years ago, the New York State Professional Development Collaborative (NYSPDC) was established with funding from the National Science Foundation's Advanced Technological Education program. NYSPDC is working to improve collaborations among technology educators at the secondary and post-secondary levels; and to provide contemporary, pedagogically sound curricular workshops for teachers that will ultimately impact student learning of technology in New York's high schools.[5] The original focus was on getting high school teachers to embrace the concept of informed design, and to have them incorporate engineering problem solving in their classrooms. Leadership teams, comprised of information and engineering technology college faculty and high school technology teachers, were trained to deliver professional development workshops for teachers throughout the state of New York. The curricular materials used in the workshops had been developed under a previous NSF project, the New York State Curriculum for Advanced Technological Education (NYSCATE).[6]

The participating high school teachers have, in fact, embraced informed design and are incorporating more engineering problem solving in their classrooms. However, the college faculty have also found the pedagogical strategies to be useful in their engineering and information technology classrooms.

Informed Design in Mechanical Engineering Technology

All too often, post-secondary engineering technology students struggle with intentionally vague design problems. How often have you heard students lament over design criteria they must first research, quantify, and justify in order to make value added decisions? It is the student's ability to apply critical thinking skills and decision-making processes in addition to effectively communicating analytical results that will enable them not only to survive but also to flourish in industry. The addition of the informed design problem solving methodology can assist faculty and students in this endeavor.

Consider the informed design process as a problem solving road map for students. The practical step-by-step approach of the informed design process affords students the ability to refine design constraints and communicate their conclusions graphically, mathematically, and technically in a laboratory report format. The informed design process reinforces Bloom's cognitive learning domain by assisting engineering technology students in identifying, analyzing, and defining the data found in an engineering design challenge. Since many engineering technology students are tactile-kinesthetic learners, the cognitive domain reinforcement that informed design affords can be a welcome addition to an ET course.

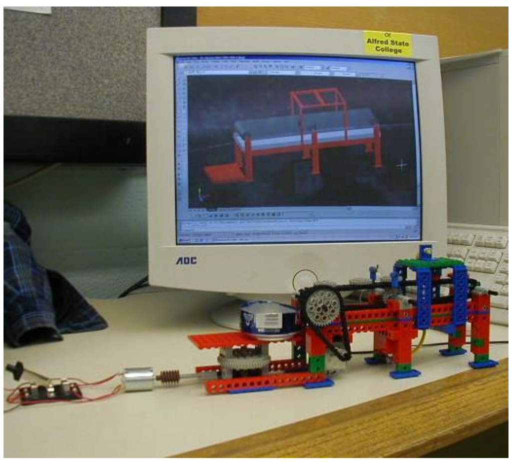
In the Mechanical Engineering Technology curriculum at S.U.N.Y. Alfred State College of Technology, the informed design process is used in both MECH 3224: Mechanical Design Principles and MECH 4224: Mechanical Systems Design. These sophomore level courses cover all aspects of a traditional machine design course using algebra, trigonometry, and basic statics to solve mechanical design problems. By design, as students progress through the material presented in both of these courses, they are required to make decisions based on their interpretation of the design criteria.

These design decisions can range from determining the most advantageous material grade for the machine's operating environment, to the selection of specific stock components that produce the highest system output efficiencies. Students are also required to research what applicable industrial codes would govern their design and then implement those design considerations into the computational analysis. In a class of fifty students, this often results in a variety of different designs and fosters a great deal of creativity and discussion as the students debate whose design best meets the pre-determined design criteria for each assignment.

The informed design process is used in the following way for the aforementioned mechanical design courses. Once the design challenge is assigned, students are to first read and digest the entire assignment. This requires clarifying the specifications and constraints stated in the design criteria. It is at this first step in the informed design process where the true value of this problem solving methodology can be seen. Prior to using the informed design process, students would immediately start their computational analyses without regard to what it was they were solving. This often resulted in incomplete and/or incorrect analysis of the problem. However, the informed design process reduces this possibility by first starting with analysis. Once specifications and constraints have been researched and quantified, computational analysis can begin.

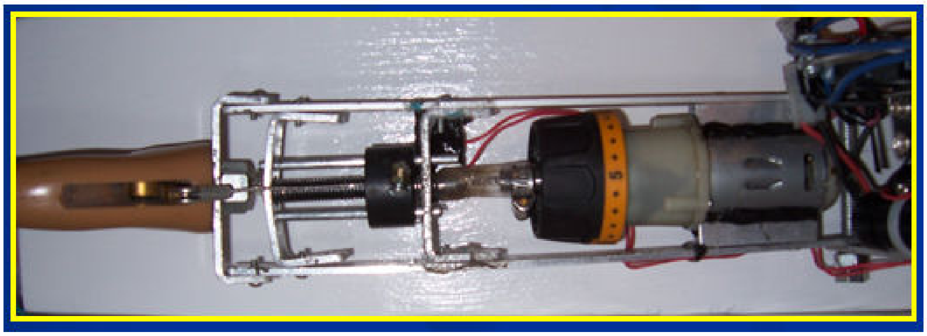
Using the informed design problem solving process allows students to submit multiple design alternatives for possible solution to a particular design challenge. Having the students generate several alternative designs and then submitting not only the alternative designs for approval but communicating in writing which design they consider to be optimal, affords an additional layer of cognitive knowledge and application assessment for the educator. It is also a powerful learning tool in terms of getting students to think about future requests from industry clients.

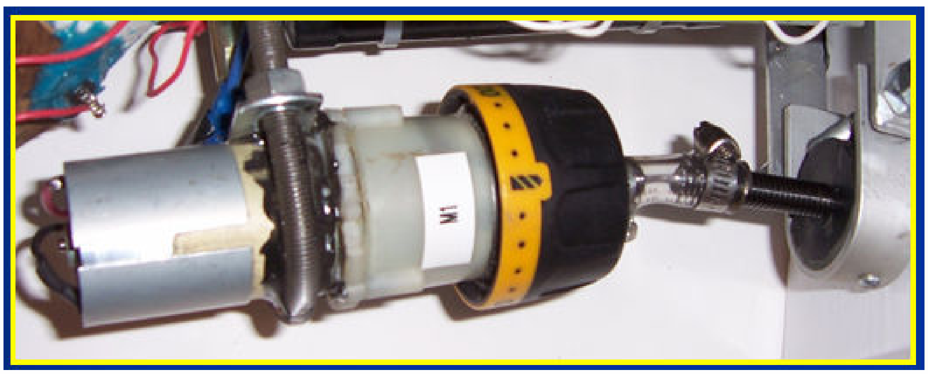
The creation of a working prototype in a machine design course complements the tactile-kinesthetic learning component. Students are required to develop a working prototype that emulates their computational and graphical solution to the design challenge. Using LEGO Engineering Educational Products, students eagerly await the opportunity to complete this step of the informed design process as seen in the illustrations below.



At some point during the course of each semester and much to the chagrin of the students, an intentional and previously unannounced revision is made to the design challenge. This revision typically manifests itself in the form of a change in the design criteria or in the project scope. The ability of engineering technologists to nimbly alter their designs offers yet another opportunity to measure how well a student applies and comprehends the design criteria. Although unpopular with the students, this act illustrates that it is indeed rare when the scope of a design challenge is static. Exposing students to change in the academic environment facilitates the necessary malleability that industry will expect of them.

Seniors in the Mechanical Engineering Technology curriculum are also using principles of the informed design problem solving methodology to assist them in their Capstone Project. During this two semester learning experience, students are continuously rendering and refining the scope of their projects to align with their Gantt charts and budgets. During the 2004-2005 academic year, a student named Chris Scott from Portville, New York used the informed design process in an intriguing way. Chris wanted to design and develop an affordable prosthetic arm for people without insurance. The informed design process served as his road map as he generated a host of alternative designs. The first designs considered using pneumatics and hydraulics for speed and strength. However, additional research illustrated these design options would not be practical from both fabrication and financial aspects. After further research, Chris decided on the use of an ACME thread in a Lead Screw application. The drive system would be a surplus drill motor. The control system would consist of three push button switches located in the sheath and operated with his appendage. The photographs below illustrate the final prosthetic arm design.





Adding the informed design problem solving process affords engineering technology students a structured and easily followed "road map" through any design challenge assignment. As the demand for skilled mechanical engineering designers and technologists knowledgeable in both the theory and application continues to increase, industrial constituents will benefit from graduates trained in the use of the informed design problem-solving format. This benefit will be evident when it takes less time for entry-level designers and technologists to complete industrial design challenges, and when the solutions to such design problems are robust and well developed. When students enter industry, contact can be maintained to determine if this methodology is currently and effectively being utilized in the workforce.

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