

## **Instructional Modules to Support Senior Capstone Design Classes**

**Gary Kinzel, Blaine Lilly, Anthony Luscher, James Piper, Rachel Murdell**  
**The Ohio State University**

### **Abstract**

In senior capstone design courses, the instructor typically presents lecture material in addition to guiding the students in design. The lecture material often includes a wide range of topics, and it is difficult to identify a single textbook that covers all relevant areas. This makes it difficult for new faculty to teach capstone design courses and considerable effort is required to develop the lectures from varied sources. A result is that the instructors often tend to cover the introductory topics superficially.

To reduce the time required for faculty to develop lecture material on design topics, we have developed using Microsoft PowerPoint a set of instructional modules that can be used as a basis for introductory lectures in capstone design. Using the modules, the preparation time for lectures is vastly reduced. The modules also help to ensure that the instructor has covered all relevant topics before the students begin their own design projects.

### **I. Introduction**

By the time that students take a capstone design course, they will have had the fundamentals in their general mechanical-engineering courses. However, they may or may not have been presented information on the issues associated with conducting and managing a large design project.

In addition, design is now commonly considered to be a topic that permeates all of mechanical engineering. Therefore, in a capstone design project, the topics may just as easily involve the thermal sciences as the mechanical sciences. Because of this, a larger percentage of a given faculty are likely to teach the capstone design course than any other course. Because of the variation in the types of faculty who might be teaching the capstone design course, it is important to have clear guidelines on the details of the topics that need to be taught.

To help faculty who might be teaching the capstone design course for the first time and to provide uniform coverage of the essential topics that need to be covered, we have been working on a set of teaching modules. The topics that we have considered so far are the design process, design concept generation, reverse engineering, and ethics.

The modules are developed in Microsoft PowerPoint and include notes and the use of multimedia. The modules have been developed with and without voice overlay so that they can be used as the basis for a lecture or supplied to the students for individual study.

Several programming platforms were considered, and PowerPoint was chosen because it has a number of desirable features. It is commonly used by engineering faculty, and it is relatively easy

to learn. It has the ability to incorporate animation, and other programs can be accessed from within it. Basic PowerPoint files will also run on multiple platforms. Therefore, the files can be developed on either a Macintosh or PC. It is also relatively easy to incorporate multimedia with PowerPoint, and it is relatively easy to add a voice overlay to the slides.

The development of the modules was supported by the NSF sponsored Gateway Coalition, which is a coalition of seven universities. One of the goals of the Gateway Coalition is to promote educational innovation and to encourage the use of technology in instruction. It also encourages team work and design projects.

This paper discusses the development of the modules and the rationale for choosing the examples presented. The modules will be available via World Wide Web and will be downloadable via FTP.

## **II. The Design Process**

In a modern mechanical-engineering curriculum, design projects will typically be located in several courses throughout the curriculum; however, these will typically be small in scope until the capstone project course is taken. Similarly, while design is discussed throughout the curriculum, the design process is often not covered in a comprehensive manner until the capstone design project. Ideally, the students will have taken courses in all aspects of mechanical engineering by the time that they take the capstone project, and a discussion of the design process allows the instructor to show how everything fits together.

Our design-process module addresses the following topics:

1. Different approaches to the design process
2. Market research
3. Target specifications
4. Concept generation
5. Evaluating designs
6. Analytical design
7. System level design
8. Detail design
9. Tolerancing issues
10. Cost issues
11. DFM/DFA
12. Prototyping
13. Testing

The presentation can be given in 30 minutes if it is desired to give just an overview; however, it also can be used as the basis for a lecture that would take approximately 50 minutes. The instructor can expand any aspect of it.

We have prepared “notes” pages for each of the slides, and the voice overlay is based on these notes pages. Because of the voice overlay, the slides can be used in three different ways. First, they can be played in a semiautomatic manner where the instructor can simply set up the computer and do nothing more than advance the slides. In the second mode, the instructor can play each slide and make additional comments. In the third mode, the instructor can disable the voice overlay and use

the slides as a basis for his/her own lecture. This mode gives the greatest flexibility since the instructor can then add or delete slides to customize the presentation. Two typical slides from the design-process module are shown in Fig. 1. The notes for the two slides are given in Table 1.

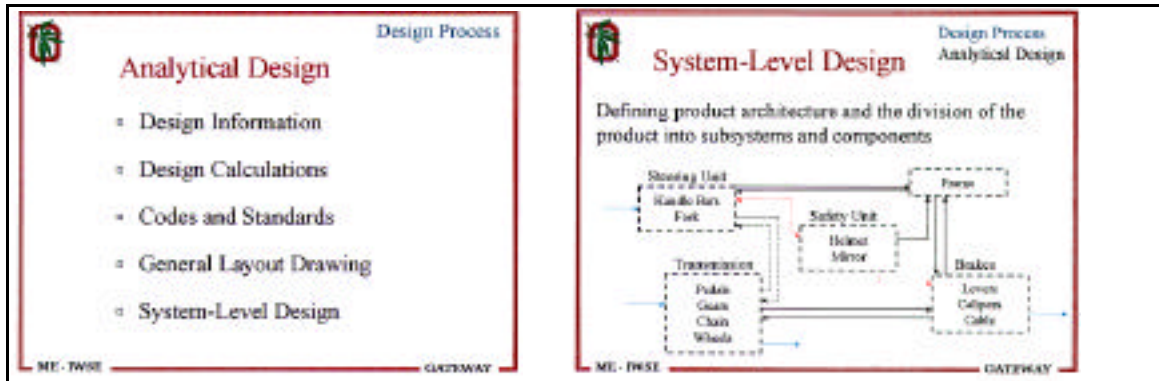


Fig. 1: Two slides from module on design process

Table 1: Notes pages for the slides shown in Fig. 1.

<p><u>Slide on Analytical Design:</u></p> <p><i>Design Information can be found in a number of references, such as Machinery's Handbook, Marks' Handbook, Roarke's Formulas for Stress and Strain, and Bralla's Manufacturing Handbook. Obviously vendors would also be a useful source for this type of information.</i></p> <p><i>Design calculations are much more refined than the initial calculations during the generation phase. Knowing the stresses that an object will be subjected to allow designers to calculate specific dimensions. Designers will often assume a dimension and then find the resulting safety factor for a situation.</i></p> <p><i>Government agencies, such as the National Highway and Traffic Safety Administration (NHTSA), the Federal Aviation Agency (FAA), or the Environmental Protection Agency (EPA) have standards and regulations already formulated. Standards can be found in other areas as well, such as the annual SAE Handbooks.</i></p> <p><i>The general layout drawings often generated using a computer-aided design (CAD) system allows the designers to begin to firm up the geometry of all the components.</i></p> <p><i>System-Level Design will be discussed in more detail.</i></p> <p><u>Slide on System Level Design</u></p> <p><i>Definition from: Product Design and Development, K. Ulrich, S. Eppinger, McGraw-Hill, Inc., 1995<sup>1</sup></i></p> <p><i>The idea of system-level design is to break down the product into its systems and then to further break down each system into subsystems. By doing this, a designer can see the intentional and incidental interactions that will take place.</i></p> <p><i>System Level Design also deals with the modularity of a design. More integrated products generally have more expensive components, but assembly is often less costly.</i></p>
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### III. Design Concept Generation

Concept generation is one of the most difficult design topics for engineering students. This topic is generally associated with creativity, and engineers tend to feel that they are not creative. The intent of this module is to aid in the generation of ideas. The module addresses the following topics:

1. What is creativity?
2. Steps to becoming more creative
3. Research and lateral thinking
4. Obstacles to creativity
5. Drawing techniques

Two typical slides from the set for design concept generation are shown in Fig. 2. Again, a voice overlay is provided, and the slides can be used in any of the ways discussed in Section II. The notes for the two slides are given in Table 2.

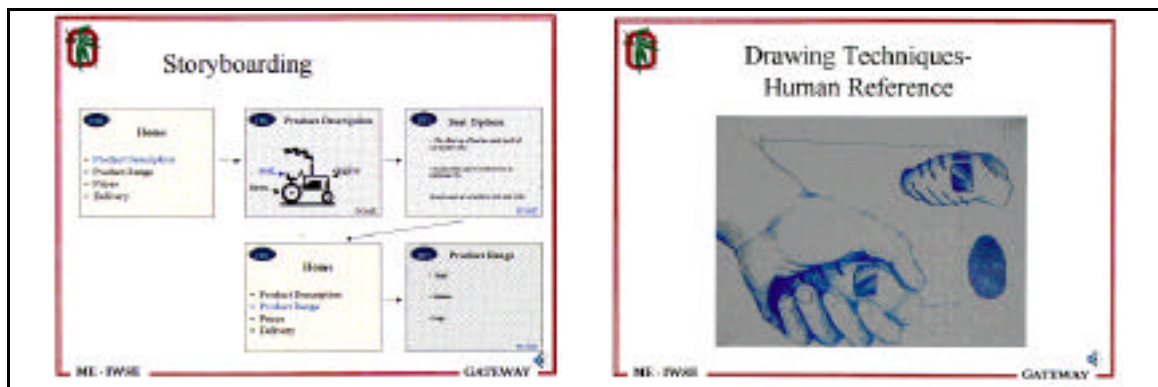


Fig. 2: Two slides from module on design process

Table 2: Notes pages for the slides shown in Fig. 2.

#### Slide on Storyboarding

*Example of a storyboard.*

*Storyboarding has been an important tool of the movie and television business for years.*

*Today it is also used with web page design, but the concept could be applied to instruction manuals or even any product design that requires the consumer to complete a sequence of tasks.*

*The advantage to the storyboarding is that the designer can see if the order of events makes sense, and if it doesn't, they are easily rearranged.*

#### Slide on Drawing Techniques

*Adding part or all of a human form gives the viewer perspective. This is especially useful for irregular shapes*

## IV. Reverse Engineering

The reverse engineering module gives an introduction to reverse engineering and discusses the design of electric hedge trimmers. Using this product, it is possible to discuss design for function, design for manufacturing, design for safety, and other issues. The types of engineering calculations needed to design such a product can also be discussed. These include the sizing of machine components such as shafts and gears, stress analysis of critical components, and mechanical linkage design. Using a consumer product as an example, it is also possible to discuss ways to cut costs in designs that are mass produced.

The module addresses the following topics:

1. General rationale
2. Methods for reverse engineering
3. Example of hedge trimmer
4. Considering environmental impact
5. Force flow ideas
6. Consideration of free-body diagrams
7. Patent issues

Two typical slides are given in Fig. 3. Again, a voice overlay is provided, and the slides can be used in any of the ways discussed in Section II. The notes for the two slides are given in Table 3.

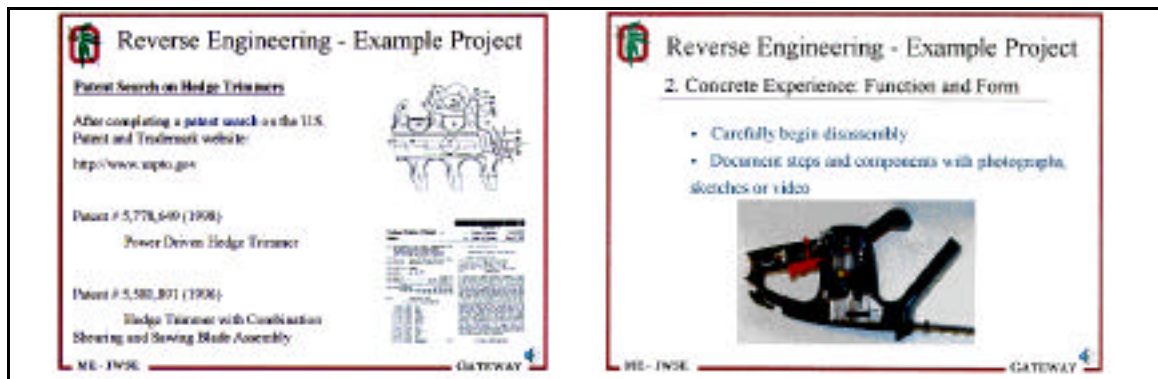


Fig. 3: Two slides from module on reverse engineering

## V. Ethics

Engineering ethics is typically covered at various points throughout an engineering curriculum; however, because it is often a central issue in design, ethics should be emphasized in a capstone design project. The intent in this module is not to give a complete coverage of all the topics associated with engineering ethics but to give a review of some of the issues involved. The module uses information from a variety of sources, but the principal source of material is the National Society of Professional Engineers' (NSPE) web page<sup>2,3</sup>.

Table 3: Notes pages for the slides shown in Fig. 3.

<p><u>Slide on Patent Search</u></p> <p><i>An important background research tool during a Reverse Engineering project is a patent search for similar designs. Patent searches allow engineers to see detailed design specifications and figures that describe a product's function and inner workings. The importance of a patent search and methods for performing patent searches is included at the end of this presentation.</i></p> <p><i>Click on the words "patent search" to be taken to the patent information slides.</i></p> <p><u>Slide on Function and Form</u></p> <p><i>The second fundamental step to Reverse Engineering is the actual disassembly of the working model. This will allow us to examine how the product is assembled, how it operates, and how complicated the design may be. Care should be taken to document these steps in order to be able to reassemble the product in the end.</i></p> <p><i>In this figure we have begun disassembling the hedge trimmer by opening its plastic case, exposing the motor, switch and cutting blade linkage.</i></p>
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The ethics module addresses the following topics:

1. Professional ethics
2. NSPE Canons of Ethics
3. Introduction to moral thinking
4. Case study on credit for engineering work
5. Case study on engineer's right to protest
6. Case study on conflict of interest
7. Case study on Ford Pinto case

Two typical slides from the ethics module are shown in Fig. 4. Again, a voice overlay is provided, and the slides can be used in any of the ways discussed in Section II. The notes for the two slides are given in Table 4.

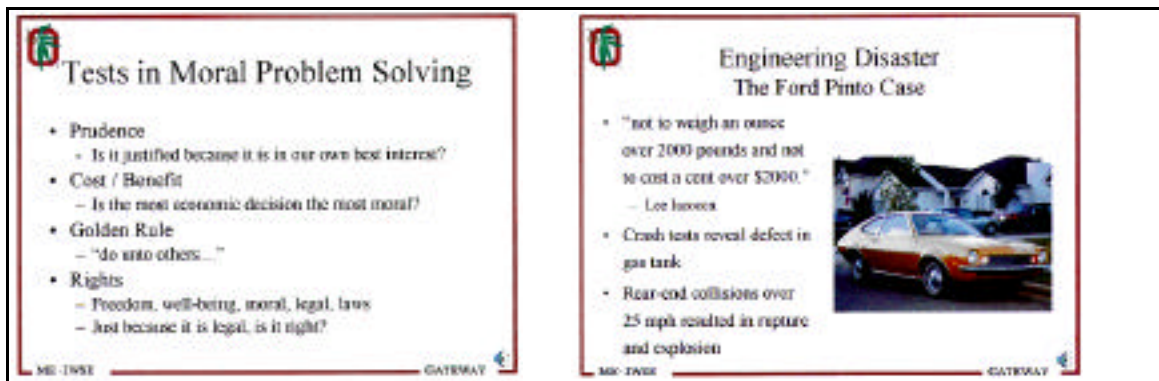


Fig. 4: Two slides from module on engineering ethics

Table 4: Notes pages for the slides shown in Fig. 4.

Slide on Moral Problem Solving

*Handling ethical dilemmas and making ethical decisions are very important elements of being a professional. In order to deal with dilemmas in an organized manner we need to begin thinking about the definitions of terms such as good, bad, right, and wrong. These may force difficult moral choices. There are several procedures and tests one can use to begin a discussion about the morality of a choice.*

Information provided by the Murdough Center for Engineering Professionalism  
Texas Tech University  
Lubbock, Texas

Slide on Pinto Case

*One of the most classic engineering ethics cases in the United States involves the story of the Ford Pinto. Designed in the mid-sixties, the Pinto was to help fill the rising demand for subcompact cars in the market. During crash testing however, the gas tank repeatedly ruptured if the car was rear-ended resulting in an explosion. Ford continued to manufacture the car, though, well aware of the faulty and dangerous design.*

## VI. Conclusions

The four modules discussed can be used to supplement an individual professor's lecture in most senior level capstone design courses. The modules can be easily modified so that they can be customized to specific text books and class emphasis. Therefore, whether they are used in whole or in part, they should reduce the amount of time required for the instructor's preparation in design classes.

The modules will be made available free upon request. Please contact the first author (kinzel.1@osu.edu).

## VII. Acknowledgments

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### Bibliography

1. K. Ulrich and S. Eppinger, Product Design and Development, McGraw-Hill, Inc., 1995<sup>1</sup>
2. <http://www.nspe.org/ethics/>
3. <http://onlineethics.org/cases/>

#### GARY KINZEL

Gary Kinzel is a professor in mechanical engineering and teaches courses in machine design, kinematics, and CAD/CAM at The Ohio State University. He is a registered professional engineer in the state of Ohio and has six years of industrial experience. He received his Ph.D. from Purdue University and has been at Ohio State since 1978. He has co-authored two books and more than 100 technical papers in the design and manufacturing areas.

#### BLAINE LILLY

Blaine Lilly is an assistant professor in departments of Mechanical Engineering and in Industrial, Welding, and Systems Engineering at The Ohio State University. He teaches courses in design for manufacturing and design for assembly in addition to courses in manufacturing. He received his Ph.D. from The Ohio State University and conducts research in CAD/CAM. He has authored approximately 30 papers and reports in the CAD/CAM area.

#### ANTHONY LUSCHER

Tony Luscher is an assistant professor in Mechanical Engineering at The Ohio State University. He teaches courses in design, stress analysis, and machine design. He received his Ph.D. from Rensselaer Polytechnic Institute, and conducts research in design for assembly with an emphasis on the design of snap fasteners. He has authored approximately 35 papers in the design and manufacturing area, and is active on design committees of ASME.

#### JAMES PIPER

James Piper is a graduate student in Mechanical Engineering at The Ohio State University. He has helped teach courses on computer aided design and assembly, and has worked on multimedia and product-design issues as part of his graduate research.

#### RACHEL MURDELL

Rachel Murdell is a graduate student in Mechanical Engineering at The Ohio State University. She has taught in CAD/CAM instructional laboratories while working on her M.S. thesis and has emphasized creativity and idea generation as part of her research.