Engineering Design in STEM Education
Engineering Design Challenge Curriculum

Multi-functional Food Cooker Design Challenge

NCETE Core Course 4

Spring 2009

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Date of Submission:
Thursday, April 9, 2009

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NCETE Core 4 Project	
Educators	Graduation Year

Multi-functional Food Cooker Design Challenge

Triple-Friendly: To End-Users, Manufacturers, and Ecology

Engineering Challenge Curriculum Project
NCETE Core 4, Spring 2009, UGA
Professor: Dr. Kurt Becker
Student: Edward Locke (elocke@uga.edu)

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Multi-Functional Food Cooker Design Challenge

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Acknowledgements

The development of this project received support and advice from Dr. John Mativo at the University of Georgia. Sincere gratitude is hereby expressed.

Career Highlights: Dr. John Mativo

Professor of Engineering at the University of Georgia

Since 1980, Dr. John M. Mativo taught various courses in mechanical and electronics engineering and related technology, at many universities in USA and Kenya, including Ohio Northern University (Ada, OH), Getty College of Arts and Sciences; Ohio Northern University (Ada, OH), Department of Technology; School of Science and Technology; University of Eastern Africa (Baraton, Kenya).

Academic Background

Dr. John M. Mativo came from Kenya, an English-speaking African country. He is currently an Assistant Professor with the Department of Workforce Education, leadership, and Social Foundations, College of Education at the University of Georgia. He is a well-accomplished scholar, and holds many academic credentials, including:

- Bachelor of Mechanical Engineering (Auburn University, Auburn, AL. 1995).
- Bachelor of Industrial Technology (Andrews University, MI (University of Eastern Africa, Baraton. Campus, 1988)
- Bachelor of Arts in Theology (Andrews University, MI, UEAB campus, 1987)
- Master's degree of Science in Mechanical Engineering (the University of Dayton, Dayton, OH, 2006).
- Master's degree of Education (the University of Georgia, Athens, GA, 1990).
- Doctor's degree of Education (the University of Georgia, 1993).

Professional and Pedagogic Experience

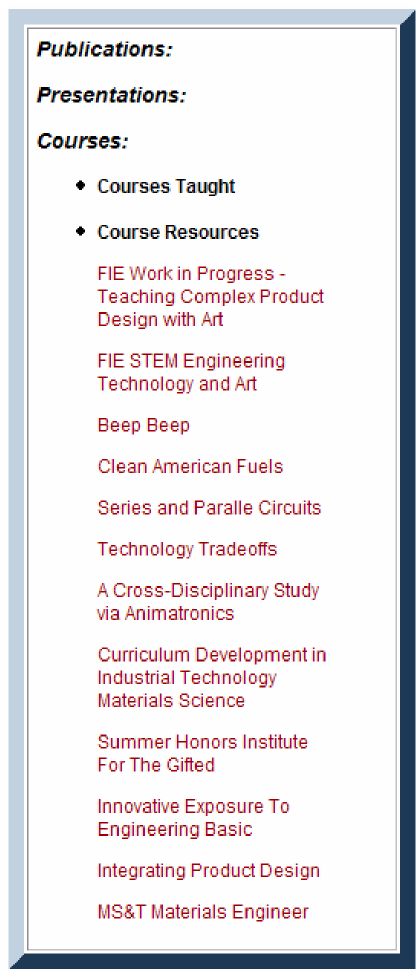
Dr. Mativo is an expert in robotic or mechatronics engineering and design; and his expertise stretches from mechanical engineering, electronics engineering, to materials science and manufacturing technology.

Courses Dr. Mativo has taught include: (1) **Engineering**: Principles of Technology (Physics, Statics and Dynamics), Senior Capstone Engineering Design, Advanced Robotics and Automation, Nonmetallic Materials and Processes, Fundamentals of Electricity, Fundamentals of Electronics (DC), Circuit Analysis (AC), Industrial Economics, Mechanical Drawing, Thermodynamics; and (2) **Technology**: Internship in Technology, Energy and Transportation, Introduction to Communication Technology, Product Manufacturing, Metallic Materials and Processes I, Robotics and Automation, Power Technology, Engines I & II, Automotive Electricity & Electronics, Suspension and Power Train, Suspension and Alignment, Engine Performance, Automotive Diesel, Welding I, HVAC; and (3) **Education**: Student Teaching Seminar in Technology, Organization and Methods of Teaching Technology, Strategies for Technology Education, and Research Methods and Statistics

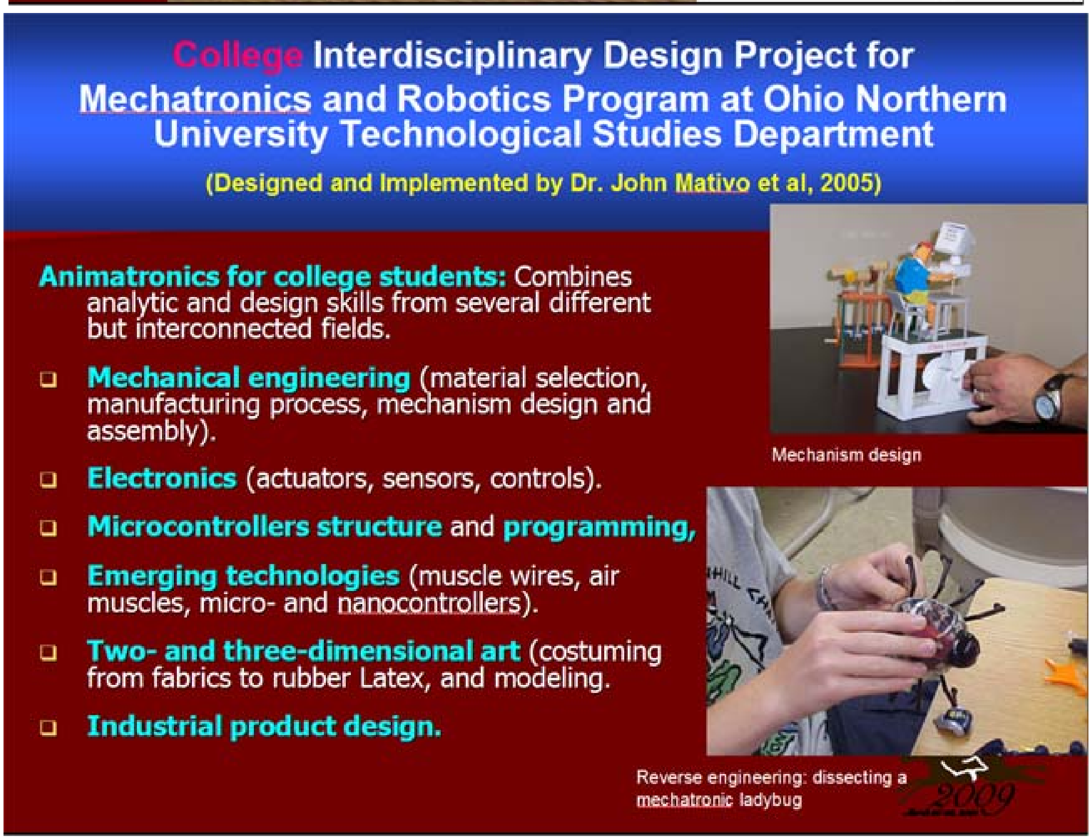
Major Accomplishments in Engineering and Technology Education

Dr. Mativo has developed many engineering and technology curriculum for high school students ("Education Model Lessons"). Many of his curriculum plans are available from http://www.coe.uga.edu/welsf/faculty/mativo/index.html

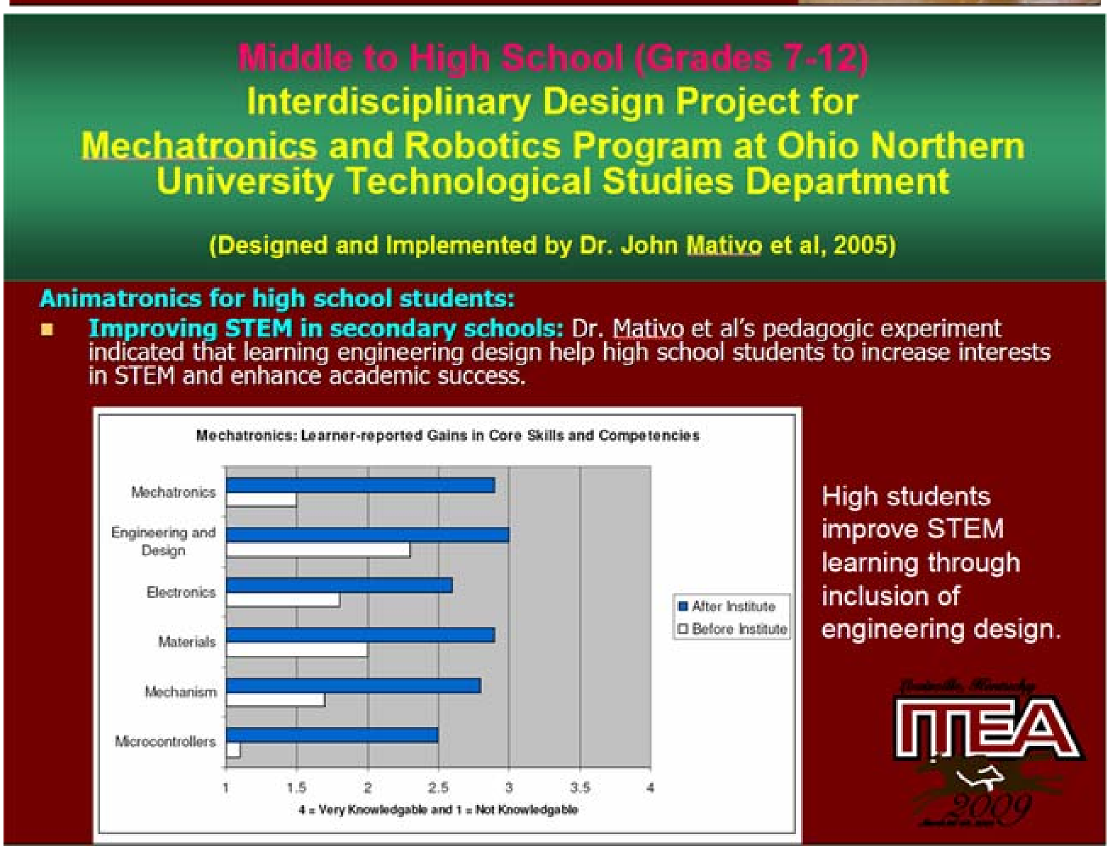
While teaching at Ohio Northern University, Dr. Mativo and Dr. Arif Sirinterlikci (2005) developed the multi-disciplinary Animatronics design project for university level senior-year technology teacher education students; and he later further develop it into a middle to high school level design project (for Grades 7 – 12), which has been tried in Ohio and proved to be enhancing the STEM education of high school students (see attached pictures).




College Interdisciplinary Design Project for Mechatronics and Robotics Program at Ohio Northern University Technological Studies Department
(Designed and Implemented by Dr. John Mativo et al, 2005)
Animatronics for college students: Open-ended and creative honors course.
Animated mechatronic blob,
Penguin,
Robotic trash can, and a
Human/monster hybrid.
The Jolly Roger
YARR
Modeling with polymer based clays


College Interdisciplinary Design Project for Mechatronics and Robotics Program at Ohio Northern University Technological Studies Department
(Designed and Implemented by Dr. John Mativo et al, 2005)
Animatronics for college students: Combines analytic and design skills from several different but interconnected fields.
Mechanical engineering (material selection, manufacturing process, mechanism design and assembly).
Electronics (actuators, sensors, controls).
Microcontrollers structure and programming,
Emerging technologies (muscle wires, air muscles, micro- and nanocontrollers).
Two- and three-dimensional art (costuming from fabrics to rubber Latex, and modeling.
Industrial product design.
Mechanism design
Reverse engineering: dissecting a mechatronic ladybug
2009


Middle to High School (Grades 7-12)
Interdisciplinary Design Project for
Mechatronics and Robotics Program at Ohio Northern University Technological Studies Department
(Designed and Implemented by Dr. John Mativo et al, 2005)
Animatronics for high school students: A grades 7-12 project (weekend program complemented by a summer capstone experience).
STEM enrichment: For gifted and talented secondary school students (sponsored by Ohio Department of Education. A three-day summer camp of four local middle school students from the gifted and talented program.
Cross-disciplinary faculty collaboration: With an art professor to strengthen the art component of the program (art and tech education modeling materials such as oil based clays, polymer and earth based clays, urethane and other polymers used).
Animatronics in daily life: My collection of animatronics toys. The cat's eyes have sensors that can respond to waving hands.


Middle to High School (Grades 7-12)
Interdisciplinary Design Project for
Mechatronics and Robotics Program at Ohio Northern University Technological Studies Department
(Designed and Implemented by Dr. John Mativo et al, 2005)
Animatronics for high school students:
Improving STEM in secondary schools: Dr. Mativo et al's pedagogic experiment indicated that learning engineering design help high school students to increase interests in STEM and enhance academic success.
Mechatronics: Learner-reported Gains in Core Skills and Competencies
Mechatronics
Engineering and Design
Electronics
Materials
Mechanism
Microcontrollers
1
1.5
2
2.5
3
3.5
4
4 = Very Knowledgable and 1 = Not Knowledgable
After Institute
Before Institute
High students improve STEM learning through inclusion of engineering design.
ITEA
2009

Organization of the Guide

This guide is organized into nine chapters.

- Chapter 1 (Overview of Major Course Design Components): It provides information about: 1) goals and objectives, 2) Instruction, 3) Assessment (using Backward Design template).

- Chapter 2 (Overview About the Engineering Design Challenge Scenario): It provides background information on the available food cookers found in major chain stores, such as Wal-Mart and Sears-K-Mart, and the possibility for better design solutions).

- Chapter 3 (The Design Challenge): It provides a brief description of the challenge, time requirements, and materials.

- Chapter 4 (Connections to National Curriculum Standards): It provides correlations to the National Science Education Standards, the Standards for School Mathematics, and the Standards for Technological Literacy.

- Chapter 5: (Preparing to Teach): It contains all of the basic information a teacher needs to know, and lists everything they need for cost estimates.

- Chapter 6 (Classroom Sessions): It provides information that will guide the teacher through each session.

- Chapter 7 (Evaluation/Assessment): It provides information that will guide the teacher through student evaluation (grading rubric, etc).

- Chapter 8 (Opportunities for Extension): It describes optional activities that are related to the basic challenge.

- Chapter 9 (Instructor Resources): It contains useful websites, YouTube video links, and online lesson plan sources.

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Chapter 1: Overview

Introduction

Intended Current Learners:

This Engineering Design Challenge is designed for the students enrolled in similar courses as follows:

1. University senior-year students at UGA: The ETES 5110 Applications of Engineering in Technological Studies course, under the newest version of the Check Sheet for Degree Requirements for the University of Georgia's B.S. in Education Degree with Emphasis on Technological Studies Technology Education Certification, in the Technology Education Major Requirements section (source: http://www.uga.edu/teched/chklist.htm). It will provide a real-world project for the application of engineering principles in solving technological problem. The description of the course reads: "Systematic approach to solving technological problems using engineering design processes. Establishment of engineering design principles to guide, to collect data, and evaluate the design process. Focus on creativity, resourcefulness, and the ability to visualize and think abstractly" (http://bulletin.uga.edu/bulletin/courses/descript/etes.html).

2. High school Grade 12 students in Georgia: The 21.47200 Engineering Applications course under the Engineering Career Pathway, prescribed by the State of Georgia Department of Education. The course description reads: "Engineering Applications is the third course in the engineering pathway. Students have opportunities to apply engineering design as they develop a solution for a technological problem. Students use applications of mathematics and science to predict the success of an engineered solution and complete hands-on activities with tools, materials, and processes as they develop a working drawings and prototypes" (http://public.doe.k12.ga.us/ci_cta.aspx?PageReq=CICTAEET).

Intended General Pedagogic Objectives:

Students will have an opportunity to

1. Review engineering and physics knowledge content related to heat transfer and electricity;

2. Learn additional engineering analytic skills; and

3. Apply these analytic skills in the "system thinking" engineering design process, to design a multi-functional food cooker.

Intended Specific Learning Objectives:

The most important specific learning objectives of this Engineering Design Challenge include:

1. To learn how to solve ill-structured and complex engineering design problems, using "Systems Thinking" concepts;

2. To learn how to critically analyze and compare existing products and systems, and to find innovative engineering design solution that will incorporate beneficial features of existing products and systems with new features;

3. To learn how to be creative through well-tested mechanisms such as brainstorming sessions.

4. To learn how to integrate engineering analytic and predictive principles and skills from various previous coursework (such as the electrical circuit analysis and heat transfer portions of high school physics, chemistry and material selection, CAD, and art), so as to solve a real-world like and complex engineering design problem.

5. To learn how to integrate available out-of-shelf components with features and components to be designed;

6. To integrate all aspects of engineering design, from not only technical perspective, but also social, economic and ecological perspectives.

The engineering analytic skills and design process explored in this real-world Engineering Design Challenge project will allow the above two categories of students to master relevant engineering analytic skills and "system thinking" design process.

1. Goals and Objectives of the Project

This Engineering Design Challenge shall allow students to integrate both "Analytic Reduction" and "System Thinking" Models of Engineering Design Process.

The "Analytic Reduction" Model of Engineering Design Process:

Several branches of pre-calculus and beginning-calculus based engineering and design subjects will be reviewed and explored, based on the Mini-Lesson model developed by Dr. John Mativo during his professorship in Ohio Northern University (pp. 5-8). Each Mini-Lesson is a challenge for students to solve a particular area of engineering analysis and design, and should involve 6 to 8 class periods and 4-8 hours of teacher preparation time. The textbooks to be used would be the same as in previous engineering analysis and technology courses (*Figure 1B*, pp. 22-23). Each Mini-Lesson would be covered within a 2-6 week period. Each Mini Lesson will help students to reduce the whole Engineering Design Challenge into separate problems to solve; but all Mini Lessons together will train students in completing the whole Engineering Design Challenge project in a systemic way. The "Analytic Reduction" Model is reflected in Mini Lesson A (Physics for Scientists and Engineers - Circuit Analysis and Heat Transfer), and Mini Lesson B (Material Selection) of the entire Engineering Design Challenge.

The "System Thinking" Model of Engineering Design Process:

This Engineering Design Challenge an open-ended project requiring students to satisfy some pre-established criteria, which leads to the creation of functional and balanced designs, without prescribing any set results. Students will be challenged to apply their engineering analytic knowledge, personal experiences, interests and talents to the process of creating an innovative team driven solution for a multi-functional, cost-effective, user-friendly and ecologically sustainable food cooking system. In this project, students will apply and reinforce their Science Mathematics, and Communications content knowledge, through an open-ended design process that results in an original and innovative solution. This Engineering Design Challenge supports the integration of mathematics, science and technology education goals defined in the National Standards. In completing this Engineering Design Challenge, students will learn to solve ill-structured and complex engineering design problems, using the theory of "Systems Thinking." The "System Thinking" Model is reflected in the extension from Mini Lesson A (Physics for Scientists and Engineers - Circuit Analysis and Heat Transfer) and Mini Lesson B (Material Selection), to additional Mini Lessons, i.e., Mini Lesson C (Design Aesthetics and Graphic Presentation), Mini Lesson D (Industrial Product Design), and Mini Lesson E (Manufacturing and Engineering Economics). The relationship between the "Analytic Reduction" Model and the "System Thinking" Model of Engineering Design Process is illustrated by *Figure 1A*.

- "Systems Thinking" concepts: "Systems Thinking" is an approach to problem solving that views "problems" as parts of an overall system, rather than reacting to present outcomes or events and potentially contributing to further development of the undesired issue or problem. "Systems thinking" is a framework that is based on the belief that the component parts of a system can best be understood in the context of relationships with each other and with other systems, rather than in isolation. In contrast to Descartes' scientific reductionism, "Systems Thinking" proposes to view systems in a holistic manner, and constitutes an understanding of a system by examining the linkages and interactions between the elements that compose the entirety of the system. Basically, "Systems Thinking" is a way of helping a person to view systems from a broad perspective that includes seeing overall structures, patterns and cycles in systems, rather than seeing only specific events in the system (Wikipedia, 2008).

- "Systems Thinking" Activities: In this Engineering Design Challenge, students are to first conduct market research and analysis of the design problem systematically and holistically, so as to formulate an overall design strategy, before actual design activities start. This step is to be done through "reverse engineering" (i.e., analysis of existing product samples) and market investigation, which should include two parts: (1) Internet search; (2) visitation to local stores that carry the relevant kitchen appliances, such as Sears, Wal-Mart, K-Mart, Target, and others.. The principles of "Systems Thinking" should be used throughout all design activities, especially in the early stages of research and analysis.

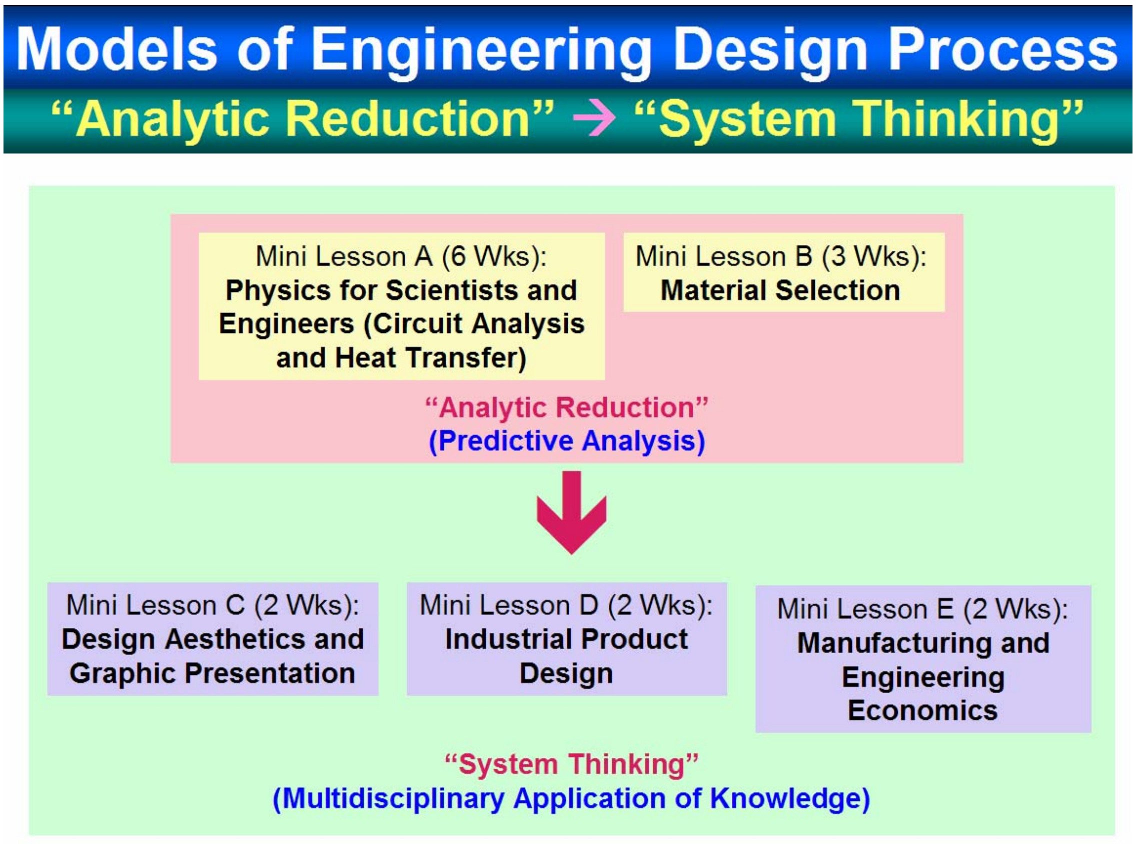


Figure 1A. The relationship between the "Analytic Reduction" Model and the "System Thinking" Models of Engineering Design Process.

The Main Issues to be Addressed:

1. At technological level: Food cooking devices constitutes one major category of food preparation appliances that exists in today's marketplace; a variety of these appliances are available, each performing one or a few closely related functions. For this category of products, there exist similar

as well as different components. For example, all food cooking appliances have a heat-generating unit operating at various temperatures and a specific food cooking unit performing a particular function (such as a pizza mold or a rice container).

2. At philosophical level: Students are to apply the principles of "Systems Thinking" to analyze the available appliances, as well as the impact of their current design on a variety of social and ecological issues, including but not limited to affordability, benefits to users, consumption of natural resources, economics and profitability, recycling, etc..

General Questions for Students:

Using "Systems Thinking" concepts to define the design problems at the above two levels, students are to answer the following questions:

- Systemic analysis: What are the similarities and differences among the various available appliances in each category, in terms of their features/components, and the overall relations among them; and how can these relationships can be understood in order to design a multi-functional food processor and a multi-functional food cooker?

- General design strategy: What are the engineering principles that can be used to solve the above engineering design problems?

- Design resource or logistics: What are the available out-of-shelf devices and components that can be incorporated into the new engineering designs? What are the devices and components that need to be designed from scratch? What are the available manufacturing technologies and materials to be used?

- Societal and ecological benefits: What are the benefits of the new design to sustainable use of the Earth's natural resources, to consumers, and to the potential manufacturers' profitability? In other worlds, how to make the new products to be designed more affordable to consumers, with a decreased consumption of raw materials per unit, while allowing the cost of purchase to drop, and at the same time, increase the products' market share?

- Safety and ergonomics: What are the factors to be considered in order to ensure user safety and comfort when operating the newly designed appliances?

General Understanding of the NCETE High School Engineering Design Process Expected of Students:

Students are to understand that this Engineering Design Challenge deals with ill-structured and complex problems. There are no single correct ways to solve the design problems. There are no "best" designs either. Instead, there are different strategies that can be used to achieve the same design objectives. Practical solutions are those that satisfy various and sometimes conflicting criteria in a balanced manner.

Reminder to Students:

Students should be aware of the changes that have occurred in engineering design practice, which have been summarized by Wicklein and Thompson (2008), including:

- Change from focus on product quantity and affordability to focus on quality;

- Change from sequential "over-the-wall engineering" with "little or no interaction between the different parts of the design and manufacturing process" to concurrent engineering based on collaborative interaction among engineers from many different fields, and representatives from marketing, manufacturing, legal, distribution, packaging, and others;

- Change from company-centered R&D with no customer input to "user-centered-design process;"

- Change from mere concern for profit margins to "Green Design" or "Sustainable Design," with "an alternative philosophy in which the design engineer is much more aware of environmental stewardship, social responsibility and economic viability."

Student Collaboration:

This Engineering Design Challenge invites students to work in groups to design, analyze, build, test, evaluate, re-design, and re-build a prototype of a multi-functional food cooker, using similar methods typical engineers and product designers use in the fields of practice. As students reflect upon the performance of their designs and move gradually toward a more functional design solutions, they learn important science content, apply concepts and principles of engineering and mathematically-based predictive analysis formulas, to improve their product planning and performance predicting skills.

- Organization of design groups: Students will work in groups of 3 - 5 members under instructor's supervision. Group members will work together to frame the overall research and design strategy, to divide the research and tasks among the members and to coordinate the efforts of individual members into achievement of group objectives.

- Coordination of design groups' activities: At each stage of the design process, each group will have a Coordinator to coordinate the activities of the members; the role of Coordinator will rotate among the team members. The Coordinator will keep a work progress log.

- Supervision of design teams: The instructor of the course will supervise the activities of each student design team and give advice when requested.

2. Instructional Components

Primary Engineering Design Challenge and Opportunities for Extension:

The whole capstone engineering experience consists of two components:

- Primary Engineering Design Challenge: Mini Lesson A (Electricity and Heat Transfer as parts of Physics for Scientist and engineers) will involve extensive very specific engineering predictive analysis (i.e., electrical circuit analysis and heat transfer) and design process. This component will be covered in Chapter 1 through 7. The primary design challenge is basically an integrative STEM project, and a PBL (Problem-Based Learning) experience.

- Opportunities for Extension:

    - Within the course: Mini Lessons B through E constitute Opportunities for Extension which involves application of generic knowledge content and skills (arts, technology and social sciences). Refer to Chapter 8 for details.

    - Beyond the course: The whole Engineering design Challenge will Mini Lessons A through E can be used as a general template for development similar Engineering Design Challenge related to other products (such as multi-functional food processor, etc.), or systems (such as home solar energy systems, etc.).

Reference Books and Standards for the Mini Lessons:

(1) For the Primary Engineering Design Challenge:

A. **Physics for Scientist and Engineers (Electricity and Heat Transfer/Thermodynamics). 6-Week Period.**

Textbooks to be Used: Most students should have one of the books below.

- For B.S. in Engineering and Technology Teacher Education Senior-Year students: (1) Part 3 - Thermodynamics, Chapters 19-22; and Part 4 - Electricity and Magnetism, Chapters 27 and 28. *Physics for Scientists and Engineers*, Volume 1, 6th Edition or 7th Edition, by Raymond A. Serway and John W. Jewett, Jr. (2) *Heat and Mass Transfer: A Practical Approach* by Yunus Cengel); relevant chapters from this textbook will be used as additional reference to supplement *Physics for Scientists and Engineers*.

- For high school Grade 12 students: Chapters/Sections 1.3 (Voltage in Electrical Systems), 1.4 (Temperature in Thermal Systems), 2.3 (Work in Electrical Systems), 3.3 (Rate in Electrical Systems), 3.4 (Rate in Thermal Systems), 4.3 (Resistance in Electrical Systems), 4.4 (Resistance in Thermal Systems), 5.3 (Energy in Electrical Systems), 5.4 (Energy in Thermal Systems), and 6.3 (Power in Electrical Systems), from *Physics in Context (An Integrated Approach)* by Michael Crawford, John Souders Jr., Leno Pedrotti, Nick G. Carter, Bonnie Rinard, Lewis Westbrook, and John Chamberlain.

Standards A:

Upon completion of the unit, students should be able to (1) understand the principles of electric circuit analysis of relations among current, voltage, resistance, power, and other parameters; and design a potentiometer, the use of breadboard in the design and testing of circuitry (as applicable in the design and fabrication of the multi-functional food cooker's temperature controller); (2) understand the basic principles of thermodynamics in terms of heat transfer (convection and radiation, etc.) and energy electro-thermal conversion; and (3) conduct digital simulation using Electronics Workbench or P-Spice, as well as other software programs.

(2) For the Opportunities for Extension:

B. **Material Selection. 3-Week Period.**

Reference Books for the Instructor: The instructor will create PowerPoints and handouts based on the information available from the reference books below, and on Internet sources.

- Chapters 3 (Engineering Materials and Their Properties), 4 (Material Property Chart), 5 (Material Selection – The Basics), 6 (Material Selection – Case Studies), 16 (Materials and the Environment), and 17 (Materials and Industrial Design), from *Materials Selection in Mechanical Design*, 3rd Edition, by Michael F. Ashby.

- Chapters 2 (Atomic Structure), 6 (Material Properties and Behavior), 12 (Ferrous Alloys), 13 (Nonferrous Alloys), 14 (Ceramic Materials), 15 (Polymers), 18 (Electronic Materials), and 21 (Thermal Properties of materials), from *The Science and Engineering of Materials, 4th Edition*, by Donald R. Askeland and Pradeep P. Phulé.

- Chapters/Sections 1 (The Structure of Materials), 2 (Properties of Materials), 7 (Selection of Plastic/Polymeric Materials), 8.1 (The Nature of Ceramics), 8.4 (Properties of Ceramics), 8.12 (Electrical Properties of Ceramics), 14 (Stainless Steel), 17 (Aluminum and its Alloys), and 20

(Selection Process), *Engineering Materials: Properties and Selection, 8th Edition*, by Kenneth G. Budinski, and Michael K. Budinski.

Standards B:

Upon completion of the unit, students should be able to (1) predict material behaviors (strength, ductility, etc.); (2) conduct material testing and experiment in laboratory settings; (3) conduct Material Selection simulation using Granta Materials Intelligence software (for information, go to http://www.grantadesign.com/) (4) correctly use engineering materials in the design project, in terms of intended product functions, user safety, and ecological impact; and (5) locate the most economical material supply that satisfy design requirements, through Internet search and other means.

C. **Design Aesthetics and Graphic Presentation. 2-Week Period.**

Textbooks to be Used: The instructor will create PowerPoints and handouts based on the information available from the reference books below, and on Internet sources.

- Chapters 29 (Promoting Products) from *Manufacturing and Automation Technology* by R. Thomas Wright.

- Relevant learning materials from the Internet would be assigned for reading. An example of relevant Website is http://graphicdesign.about.com/.

Standards C:

Upon completion of the unit, students should be able to apply principles of two-dimensional design and three-dimensional design, in the designing of product logos and other graphic elements, graphics, in product fabrication and presentation, using Adobe PowerPoint and Photoshop, PhotoStory and other software.

D. **Industrial Product Design. 2-Week Period.**

Textbooks to be Used: The instructor will create PowerPoints and handouts based on the information available from the reference books below, and on Internet sources.

- Unit 6/Chapters 18-20 (Designing and Engineering Products) and Chapter 35 (Computer and Product Design), *Manufacturing and Automation Technology* by R. Thomas Wright; and

- Relevant materials from the Internet, such as Wikepedia Website at http://en.wikipedia.org/wiki/Industrial_design (for a suggested list, see Chapter 9, p. 179).

Standards C:

Upon completion of the unit, students should be able to (1) apply the NECTE-adopted High School Engineering Design Process as applicable to product design (*Figure 3*); (2) understand many dimensions of design, such as technological, ecological, social, and ergonomics; (3) produce 3D digital models of the designed components and assemblies using Autodesk Inventor software, and (4) fabricate design idea mock-ups, and functional working prototype.

E. **Manufacturing and Engineering Economics. 2-Week Period.**

Textbooks to be Used: The instructor will create PowerPoint files and handouts based on the information available from the reference books below, and on Internet sources.

- Unit 4/Chapters 9-15 (Secondary Manufacturing Process), Chapters 28 (Developing Marketing Plans), and 32 (Maintaining Financial Records), *Manufacturing and Automation Technology* by R. Thomas Wright

- Relevant materials from the Internet source, such as the interactive Break-Even Chart at http://connection.cwru.edu/mbac424/breakeven/BreakEven.html). For a suggested list, see Chapter 9, p. 181.

Standards E:

Upon completion of the unit, students should be able to (1) use CNC equipments to make a prototype of the design, if such equipment and previous experience are available; and (2) apply some principles of engineering economics, such as budgeting, accounting and break-even chart.

Class Schedule for the Whole Course:

(1) For the Primary Engineering Design Challenge:

Mini Lesson A (6 Weeks): **Physics for Scientists and Engineers (Circuit Analysis and Heat Transfer)**				
Wk	**Session ***	**Mini Lesson Topic**	**Assignment (Due Week → Credit)**	**Reading**
1	1	Introduction to (1) Engineering Design Challenge, and (2) NCETE High School Engineering Design Process	Group and Company Report on Existing Products (Due: Week 4 → 5 Points)	Serway & Jewett** Ch. 27, 28 or Crawford et al*** Ch/Sec. 1.3, 2.3, 3.3, 4.3, 5.3 and 6.3
	2	Market Research		
	3	Ohm's Law and Circuit Analysis		
	4	Reverse Engineering		
2	5	Potentiometer Design (Computation)		
	6	Potentiometer Design (Simulation with ElectronicsWorkbench)		
	7	Potentiometer Design (Breadboard Testing)		
	8	Potentiometer Design (Report Writing)		
3	9	Heat Transfer (Lecture/Video/Display)	Group and Company Report on Heat Transfer Computations (Due: Week 5 → 5 Points)	Serway & Jewett** Ch. 19-22, or Crawford et al*** Ch/Sec. 1.4, 3.4, 4.4, 5.4
	10	Heat Transfer (Computations)		
	11			
	12			
4	13	Improving Design of Potentiometer (Fabrication and Testing)	Group and Company Report on Potentiometer Design and Testing (Due: Week 6 → 5 Points)	
	14			
	15			
	16			
5	17	Design of Electro-Thermal Interface and Food Containers (Supervised Student Activity)	Group and Company Report on Design of New Food Cooking Electro-Thermal Interface and Food Containers (Due: Week 8 → 5 Points)	
	18			
	19			
	20			
6	21			
	22			
	23			
	24	Quiz A (Electricity and Heat Transfer) →5 Points		

Note:

* **For high school Grade 12 students in Engineering and Technology Career Pathways:** Basically, this unit (Mini Lesson) will be taught in a block schedule in which classes meet for approximately 90 minutes, 4 days per week. Each lecture will last 15-30 minutes; and this will leave 60-45 minutes for student works in the classroom.

For B.S. in K-12 Engineering and Technology Teacher Education Senior-Year students: Basically, this Mini Lesson will be the 1st part of a 4-credit unit Senior-Year Design course, meeting 2 days a week (3 hours each). Each lecture will last 15-30 minutes; and the balance of classroom meeting time is reserved for student works.

Lecture is usually based on PowerPoint presentation and can include demonstration of artifacts or skills and Internet video shows. Each lecture will be followed by a corresponding student activity.

** For high school Grade 12 students.

*** For B.S. in K-12 Engineering and Technology Teacher Education students.

(2) For the Opportunities for Extension:

Mini Lesson B (3 Weeks): **Material Selection**				
Wk	**Session ***	**Mini Lesson Topic**	**Assignment (Due Week)**	**Reading**
7	1	Material Properties and Applications (Lecture, Internet Video Show, Sample Display)	Reflection Paper on Material Selection Mini Lesson, or PowerPoint presentation (Due: Week 10 → 5 Points)	Instructor's materials
	2			
	3	Granta Materials Intelligence (Tutorial)	Group and Company Report on Material Selection and Suppliers (Due: Week 11 → 5 Points)	
	4	Granta Materials Intelligence (Material Selection Exercise)		
8	5	Granta Materials Intelligence (Material Selection for the Design Challenge)		
	6			
	7	Search for Suppliers of Selected Materials Through Internet and School Facility Visit		
	8	Quiz B (Material Properties and Selection) →5 Points		
9	9 - 12	Semester Midterm Break. No Class Meetings. Time to Complete Previous Assignments		

Mini Lesson C (2 Weeks): **Design Aesthetics and Graphic Presentation**				
Wk	**Session ***	**Mini Lesson Topic**	**Assignment (Due Week)**	**Reading**
10	1	Elements of Aesthetics (Points, Lines, Surfaces, 2D Shapes, 3D Bodies, Colors) and Product Exterior Design	Reflection Paper on Design Aesthetics and Graphic Presentation Mini Lesson, or Collection of Design Aesthetics Samples (Due: Week 13 → 5 Points)	Instructor's materials
	2	Company Logo Design	Logo or Packaging Design (Due: Week 14 → 5 Points)	
	3	Product Packaging Design		
	4			
11	5	Photoshop Tools (Lecture/Demonstration/Exercise)		
	6			
	7	PowerPoint Tools (Lecture/Demonstration/Exercise)		
	8	Quiz C (Design Aesthetics and Graphic Presentation) →5 Points		

Mini Lesson D (2 Weeks): **Industrial Product Design**				
Wk	**Session ***	**Mini Lesson Topic**	**Assignment (Due Week)**	**Reading**
12	1	Review: NCETE High School Engineering Design Process	Concept Maps on Industrial Product Design (Due: Week 14 → 5 Points)	Instructor's materials
	2	Product Design Related Issues (Ergonomics, Product Safety, UL Testing, Patent and Copyright Application)		
	3	Coaching: Computer-Aided-Design/Drafting (Additional Tools)	Design Presentation (Incorporation of Principles of Ergonomics and User Safety) (Due: Week 15)	
	4			
13	5 - 7	Completing CAD 3D Modeling and 2D Working Drawings		
	8	Quiz D (Industrial Product Design) →5 Points, and Presenting CAD 3D Modeling and 2D Working Drawings (for B.S. in K-12 Engineering and Technology Teacher Education Senior-Year students ONLY)		

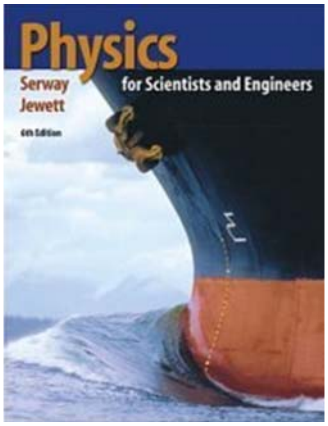
Mini Lesson E (2 Weeks): **Manufacturing and Engineering Economics**				
Wk	**Session ***	**Mini Lesson Topic**	**Assignment (Due Week)**	**Reading**
14	1	Secondary Manufacturing Process and Good Design Practice (Lecture/Internet Video/Sample Display/Coaching)	Concept Maps or PowerPoint Presentation on Manufacturing and Engineering Economics (Due: Week 17 → 5 Points)	Instructor's materials
	2			
	3	Modern Manufacturing and CNC Prototyping (Lecture/Internet Video/Sample Display)		
	4			
15	5	<u>For B.S. in K-12 Engineering and Technology Teacher Education students</u>: CNC Prototyping (Supervised Lab Manufacturing Activity) <u>For high school students:</u> Completing CAD Design and Drafting Activity ****	Completing CNC Prototyping****	
	6			
	7			
	8	Developing Marketing Plans (Break-Even Chart)	Break-Even Chart Exercise (Due: Week 16)	Internet *****

<table>
<tr><th colspan="5">Beyond the Mini Lessons (2 Weeks):
Time to Complete the Project</th></tr>
<tr><th>Wk</th><th>Session *</th><th>Mini Lesson Topic</th><th>Assignment (Due Week)</th><th>Reading</th></tr>
<tr><td rowspan="3">16</td><td>1</td><td colspan="2">Quiz E (Manufacturing and Engineering Economics)</td><td rowspan="5">None</td></tr>
<tr><td>2</td><td colspan="2">PowerPoint and Concept Maps presentations</td></tr>
<tr><td>3 - 4</td><td colspan="2" rowspan="2"><u>For B.S. in K-12 Engineering and Technology Teacher Education students</u>: Completing CNC Prototyping Activity

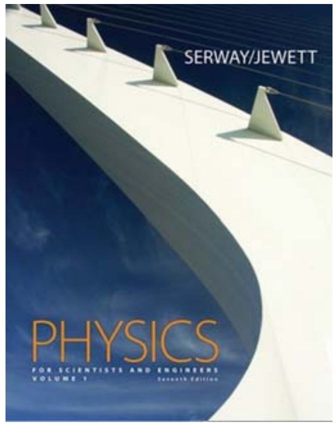
<u>For high school students:</u> Completing CAD Design and Drafting Activity</td></tr>
<tr><td>17</td><td>5 - 8</td></tr>
<tr><td>18</td><td>9 - 12</td><td colspan="2">Final Design Presentation and Critique
Submission of Engineering Design Challenge Portfolio</td></tr>
</table>

<u>Note:</u>
**** The prototyping activity is for B.S. in K-12 Engineering and Technology Teacher Education Senior-Year students ONLY, EXCEPT in well-equipped high school where CNC labs are available and where CNC manufacturing course have been previously taught to high school Grade 12 students enrolled in Engineering and Technology Career Pathways. For most of high school, this block of time will be used to complete writing assignments and CAD modeling and drafting works.
***** For Break-Even Chart online, go to
http://connection.cwru.edu/mbac424/breakeven/BreakEven.html

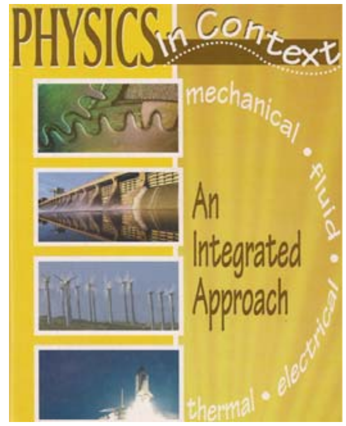
<u>Total Number of Weeks: 18</u>



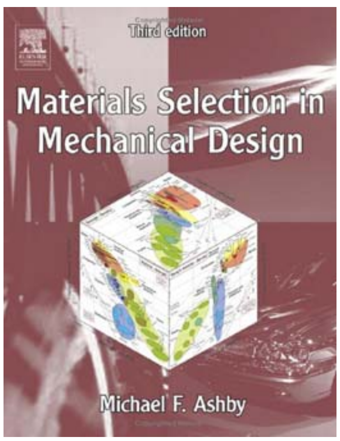
Physics for Scientists and Engineers, Volume 1, 6th Edition



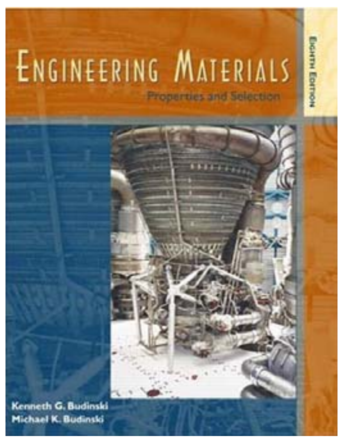
Physics for Scientists and Engineers, Volume 1, 7th Edition



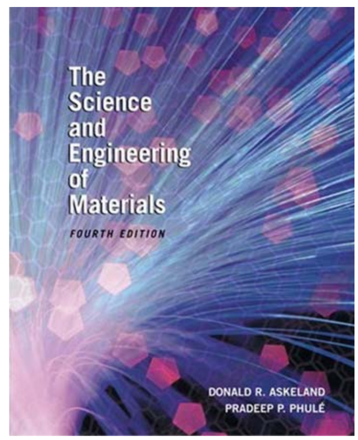
Physics in Context (An Integrated Approach)



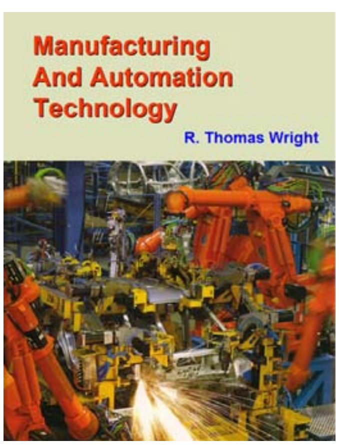
Materials Selection in Mechanical Design, 3rd Edition



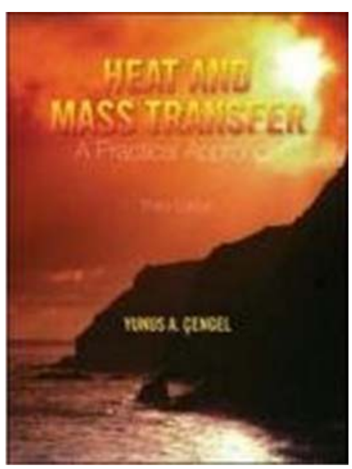
Engineering Materials: Properties and Selection, 8th Ed.



The Science and Engineering of Materials



Manufacturing and Automation Technology



Heat and Mass Transfer

Figure 1B. Textbooks to be used again as references.

3. Assessment (using Backward Design template)

The assessment of student performance is based on the "Backward Design Template," originally developed by the instructors of NCETE Core 4 Course, with reference to the following:

- Backward Design Process (Wiggins & McTighe, 2005);
- Making Classroom Assessment Work (Davies, 2000);
- Universal Design (Curry, 2003).

Assessment for the Primary Design Challenge Mini Lesson A (Physics for Scientist and Engineers - Heat Transfer and electricity)

Introduction

Unit Title	Multi-functional Food Cooker Design Challenge
Content/Topic Area(s)	Physics for Scientist and Engineers (Electrical Circuit Analysis and Heat Transfer)
Time Frame	• <u>Coverage of Content/Topic Area(s):</u> 6 weeks for reviewing the principles of Electrical Circuit Analysis and Heat Transfer, and applying them in the design, fabrication and testing of a multi-resistance potentiometer. • <u>Design Process:</u> The Primary Design Challenge will be extended into the design and prototyping of a multi-functional food cooking device. The whole design project will take one full semester to complete.
Description of the Learners	Learners include the following two groups of students, both male and female (due to the fact that this is a newly proposed project, the number of students and their gender percentage composition is yet to be determined): 1. High school students in the Graduation Year (Grade 12), between the ages of 17 and18 years old; and 2. University undergraduate senior-year students, between the ages of 21 and 23, in the Proposed B.S. Degree in K-12 Engineering & Technology Teacher Education Program (presented at ITEA 2009 Conference. For details, Refer to Appendix A1). The above students will be fairly mature cognitively and socially, having (1) accumulated enough engineering analytic skills (including CAD programs such as Autodesk Inventor or

<table>
<tr><td></td><td>SolidWorks) needed for the project; (2) experience with basic engineering design process through collaborative teamwork projects; and (3) experience making design ideation sketches and using Engineering Notebook. They would need coaching from the instructors on systematically integrate their previously gained skills and knowledge into a more complex system design that take into consideration all factors relevant to engineering design (social, economic, ecologic, ergonomics, etc.), beyond mere technological consideration. In addition, they would need to be taught additional specialized engineering analysis and design skills and processes, so as to optimize their engineering design experience, in a “system thinking” mode of real-world engineering design and prototyping environment.

Some learners might have disabilities that might impact their developmental levels, which might include expressive language, reading, writing, and arithmetic disorders, etc. All learners of this unit have demonstrated a broad range of learning preferences, such as the:
• Option to listen and observe rather than take continuous notes;
• Demonstration of the teacher-directed concepts being taught;
• Modeling of learning strategies;
• Ability to demonstrate what they know and can do in ways that are both teacher-directed and that allow for learner-centered creativity.

All possible measures would be taken to accommodate the special needs of students with the above disabilities and preferences, under the student-centered pedagogic principles.</td></tr>
<tr><td>Context of the Unit</td><td><u>Pre-requisite taught before</u>: Both groups of students would have
• Under the current conditions of high school technology education curriculum:
    o Previously taken courses in basic electronics, pre-calculus mathematics, chemistry, and physics at middle or high schools (Grades 6-11), which is enough for participating in this engineering design challenge, for all practical purposes.
    o Previously trained in basic science lab experiment process; such experience can be used in this engineering design challenge.

<u>Blocks of time available for teaching and learning and position of the unit within the year or program</u>:
• <u>For high school students</u>: Under the Proposed Model for Infusing Engineering Design into K-12 Curriculum, Engineering and Technology would become a mandated part of regular K-12</td></tr>
</table>

	curriculum. The blocks of time available for teaching and learning and position of the unit within the year or program would be re-arranged accordingly. Basically, this unit will be taught in a block schedule in which classes meet for approximately 90 minutes, 4 days per week. • For university students pursuing a B.S. degree in K-12 Engineering and Technology Teacher Education: 4-hours (one day) per week classroom meeting time (including lab experiment, simulation and production, plus 3 hours per week study and teamwork, would be required. Availability of instructional and learning technologies: Internet resource, chapters from textbooks listed on Chapter 9, p. 168. WebCT, laboratory experiment, digital simulation with Electronics Workbench or P-Spice, shall be used.
Description of the Learning	Throughout the semester-long design process, students would learn: • Engineering and technology: Additional engineering analysis, experimental and simulation skills not covered in previous courses but specifically needed for the project, in full classroom lecture setting, or in individual or group tutoring. The digital simulation programs include Autodesk Inventor, Electronics Workbench, and Granta Materials Intelligence. • Design presentation technology: Additional design presentation skills not covered in previous courses but specifically needed for the project, in full classroom lecture setting, or in individual or group tutoring. The digital design presentation programs include Adobe Photoshop, Microsoft Excel and PowerPoint, and PhotoStory. • Appropriate application of engineering and technology: The social, ethical, ecological, ergonomic and other aspects that interact with engineering design and technology usage (example: how to balance profit and ethics?); • Capstone engineering design process: The "System Thinking" model of open-ended and holistic engineering design process, integrating several branches of STEM (electrical circuit analysis and heat transfer, and math-based computations). For this Primary Design Challenge, student will: • Be briefly introduced to NCETE High School Engineering Design Process (*Figure 8A*, p. 143); • Review principles of electric circuit analysis and heat transfer covered in previous physics courses; • Apply these principles in the design, fabrication and testing of a potentiometer.

Main Learning Results for the Primary Design Challenge

Content Area(s)	Physics for Scientist and Engineers (Heat Transfer and electricity).
Standard Label(s)	*Standards A. Physics for Scientist and Engineers (Heat Transfer)*
Standard(s) & Descriptor(s)	**Students will understand the process of heat transfer and the application and design of a potentiometer** *Electrical energy can be transformed into thermal energy, and how a potentiometer can be designed and fabricated and used to change temperature of a thermal-conductive metal plate.* *Ohm's Law defines the relations among voltage, resistance and current. In household usage, voltage supplied by electrical outlets remain constant (220V); V = IR; the current flowing in the circuit is inversely proportional to the resistance; thus, a potentiometer can be designed such that the current flow can be adjusted according to the resistance of the resistor connected to the on-off switch. The variable current supplied by the potentiometer can supply variable amount of electrical energy which in turn can be transformed into variable amount of thermal energy, to generate various temperature needed in different cooking tasks performed by different food preparation devices (such as rice cooker, slow cooker, etc.). The electric power in wattage of various cooking devices can be found on the products' packages. The formula for power P = IV can be used to find the electric current needed to generate certain temperature for a particular cooking device; and the value of the current can be used to find the various resistors needed in the potentiometer to be designed.*
Grade Level (Indicate)	For high school students: Grade 12. For B.S. in K-12 Engineering and Technology Education students: Senior year.
Performance Indicator(s)	*Students should learn how to* *1. Study the existing products through reverse engineering.* *2. Analyze, design electrical circuits and predict the behaviors of each component in the circuit, using (a) pen-and-pencil predictive computation; (2) simulation; and (3) lab experiment and fabrications.* *3. Find the most suitable electrical components in the market,*

Stage A-I: Identify Desired Results: Content and Performance Standards

IA. Content and Performance Standards
IB. Enduring Understandings
IC. Essential Questions

A-I-A. What key *knowledge* and *skills* will learners acquire as a result of this unit?

Learners will know: (Content Standards)	*Ohm's Law can be used in circuit design and analysis.* *Principles of heat transfer can be used to learn the principle of conservation of energy and the way electrical cooking devices work.*
Learners will be able to: (Performance Standards)	*Students should be able to* *1. Safely disassemble a few typical food cooking devices and analyze their engineering parameters (a reverse engineering process),* *2. Correctly use ohm's law (V = IR) and the formula for power (P = IV) to make predictive computations;* *3. Simulate the design in ElectricWorkbench software;* *4. Design the electrical circuit used in a potentiometer that can generate a variable range of electric current that will transform into variable temperature for different food preparation processes;* *5. Test the design on a breadboard and with multi-meters, to connect the potentiometer with a thermal conductive metal plate and a container filled with water and to measure the temperature.* *6. Select a potentiometer available in the market that can perform similar functions as the one designed and tested in item #4 and #5, through Internet search and store visitation (Radio Shack, etc.)*

A-I-B. What *enduring understandings* are desired?

Students will understand that:	*Energy can be transformed from one form to another (for example, from electrical to thermal, such as in the food cooking appliances). During the process of heat transfer, the energy is conserved. However, not all energy transformed is usable. Thus, there is the issue of efficiency.*

A-I-C. What *essential questions* will guide these units (Mini Lessons) and focus teaching and learning?

In the following tables, essential questions for each Mini Lesson are listed. According to McKenzie, "Essential questions are questions that resonate within our hearts and our souls. They are central to our lives. Most important thought during our lives will center on such essential questions […] would be at the center of all the other types of questions. All the other questions and questioning skills serve the purpose of 'casting light upon' or illuminating essential questions. Most essential questions are interdisciplinary in nature. They cut across the lines created by schools and scholars to mark the terrain of departments and disciplines. Essential questions probe the deepest issues confronting us . . . complex and baffling matters which elude simple answers: Life - Death - Marriage - Identity - Purpose - Betrayal - Honor - Integrity - Courage - Temptation - Faith - Leadership - Addiction - Invention - Inspiration. […] Essential questions are at the heart of a search for Truth. Many of us believe that schools should devote more time to essential questions and less time to trivial pursuit." (McKenzie, 2009).

According to the rubrics for this curriculum development project, "the goal of an essential question is to scaffold and extend a learner's capacity" for: (1) "Posing problems;" (2) "Gathering information;" (3) "Thinking about possibilities;" (4) "Making decisions;" (5) "Understanding and caring about different perspectives;" and (6) "Reasoning ethically. In addition, the "essential questions" (1) "Require learners to evaluate, synthesize, or analyze new information;" (2) "Cannot be answered with 'yes' or 'no'; (3) "Help learners understand their environment and its realities;" (4) "Present learners with situations that require them to invent, to make a decision, or to plan a course of action;" (5) "Can begin with words such as 'Why,' 'How," "Which,' etc.; and (6) "Can be generated by both learners and teachers."

Resources for developing essential questions include the following:

- Cushman, K. (1989, June). Asking the essential questions: Curriculum development. *Horace, 5*(5). Retrieved May 23, 2005, from http://www.essentialschools.org/cs/resources/view/ces_res/137

- McKenzie, J. (2001, February). From trivial pursuit to essential questions and standards-based learning. *From Now On: The Educational Technology Journal, 10*(5). Retrieved May 23, 2005, from www.fno.org/feb01/pl.html.

Teacher-generated Essential Questions:	*1. Why electrical energy can be transformed into thermal energy?* *2. How are the electrical current and temperature related in the food cooking devices?* *3. How are the resistance in the potentiometer and temperature in the food cooking devices related?* *4. Why there are differences between the results of predictive computations and the results of laboratory experiment?*
Learner-generated Essential Questions:	*1. In terms of chemistry, what is the difference between electrical energy and thermal energy?* *2. What does a potentiometer really do in the electrical circuitry?* *3. What is the root cause of temperature change?* *4. What are the benefits of reverse engineering?*

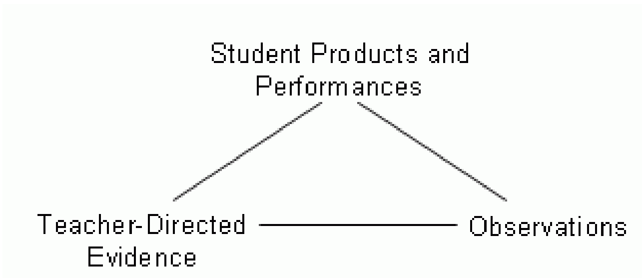
Stage A-II: Determine Possible and Acceptable:

A-II-A. Sources of Evidence of Student Learning

A-II-B. Media and Materials
A-II-C. Teaching Methods

A-II-A. Possible and Acceptable Sources of Evidence of Student Learning

Possible and acceptable sources of evidence will be collected from triangulating assessment data:



Student Products and Performances (i.e., Performance Tasks) via Technology for the Learning and Social Environments

Performance Task

The Performance Task for the Primary Design Challenge (Mini Lesson A) is based on the Teacher-generated Essential Questions.

The description of this performance task is presented in three phases:

Phase 1: Time and opportunity to consider the question.

Phase 2: Design and development of the task.

Phase 3: Demonstration of what has been learned.

Phase 1: Learners will first be given a review of the most important principles of physics covered in the Mini Lesson, and then given time and opportunity to consider the question:

- Individual time at and away from school (review of the most important principles of physics covered in the Mini Lesson);

- Time to discuss in small groups of four to five during class (exploring answers to the above four questions);

- Time to ask questions of the teacher (through e-mail, informal memo, and personal communication in and outside of classroom hours);

- Time to share and exchange ideas via whole class discussion:

- Individual ideas communicated verbally in front of the group members; or
- Individual ideas processed in groups and then group ideas presented by a group representative to the whole class.

Phase 2: Whole class discussion process will be followed by lab activities:

1. Reverse engineering: Under the supervision of the instructor, groups of three students will learn (1) how to safely disassemble some of the food cooking devices and understand the inner workings of the products (*Figure 2B*, p 44); (2) collect relevant data (wattage) from the Internet, or the packaging or the products' components; and (3) using the data, students will compute the resistance needed to design a potentiometer; the calculations will be tabulated (Tables 5B and 5C, pp. 69-70); and (4) design a potentiometer circuit with pen-and-paper computations with formulas listed at the end of Table 5B, simulate the circuit design in ElectronicsWorkbench software, and test the design with wires, resistors and breadboard. The self-built potentiometer is now completed. After each group of three students complete the reverse engineering activities on one sample food cooking device, the Group Coordinator will assemble all computations and analysis into a Group Report on Existing Products, submit it to the Class Coordinator to further synthesize into a Company Report on Existing Products, to be presented to the whole class. Use a digital camera to record the reverse engineering process.

   Student Collaboration**:** The whole class will be first divided into groups of three students (to be formed by lottery), and one group member will be elected by lottery as the Group Coordinator to coordinate group activities. Each group of three students will work on one existing food cooking device. During this step, the Group Coordinators will select by lottery a Company Coordinator to coordinate the works of all groups.

2. Potentiometer design and testing: Based on the data provided in the Company Report on Existing Products, and on given parameters (such as the 20-minute time to reach a given temperature in a given volume of a container, with a given surface area and thickness of the electro-thermal interface), new values of current and resistance will be calculated, and a potentiometer will be designed by each group of three students, using three methods, i.e., (1) pen-and-pencil computations, (2) breadboard and (3) Electronics Workbench software.

3. Temperature measurement: The student-built potentiometer will be connected to the metal containers of the existing cooking devices through their electro-thermal interface (*Figure 2B*, P. 44); the containers will be filled with water; after the power is turned on for 20 minutes, the temperature of the water will be measured at each setting of resistance values of the potentiometer. Upon completion of this step, students will search the Internet, such as the website

of RadioShack at http://www.radioshack.com/home/index.jsp, to find a ready made potentiometer that can perform the required functions with similar electrical settings. If an economical one can be found, then it will be purchased for adaptation with the multi-functional food cooking appliance, and tested with the existing appliances. Students will learn that it is better to use stock items rather than building up from scratch.

Student Collaboration**:** For these 2nd and 3rd steps, the whole class will be divided into groups of five students (to be formed by lottery), and one group member will be elected by lottery as the Group Coordinator to coordinate group activities. The Group Coordinators will select by lottery a Company Coordinator to coordinate the works of all groups. Each group of five students will work collaboratively on one group solution for the design of a potentiometer that has at least 10 resistance settings. Upon completion of this step, the Group Coordinators will present the solution to the whole class, which will collectively select one best solution, and incorporate the good elements from other solutions, to create the Company Potentiometer Design. The Group Coordinators and the Company Coordinator will then collectively write the Company Report on Potentiometer Design and Testing.

For details on the above activities, refer to Chapter 2 and 3 (pp. 40-53).

Requirement for demonstrating what students have learned:

After the lab activities, each group of four to five students will discuss the results, and write a group report that analyze the experiment and answer the above four essential questions. For the group report, each student will be required to write a portion of it. The report need to include:

1. Statement of the problem being investigated (listing the above four essential questions);

2. Form a hypothesis (an attempt to answer the above four essential questions based on the understanding of physics knowledge content taught in the textbook and in the instructor's lecture); and make predictions based on analytic computations.

3. Describe the lab activities, the results, and the conclusions;

4. Use the conclusions to answer the above four essential questions.

Phase 3: Teacher and students consider appropriate ways for demonstrating what has been learned.

Written laboratory report requirements: Each group of three students will collectively submit three reports for this Primary Design Challenge. Using the digital templates provided by the instructor (for details, refer to Appendices A2a, A2b, and A2c), each student will work on one portion of each report and proof-read the others' works; and the Group Coordinator will assemble all pieces of computations and statements into a whole report (i.e., with Microsoft Word's Copy and Paste tools).

- Company Report on Existing Products: This should include the analysis of the components of the existing food cooking devices (functions, locations, outlooks, shapes, etc.), computations, data tables and diagrams related to electrical analysis, explanations and conclusions (Due: Week 4).

- Company Report on Heat Transfer Computations: This should include computations, data tables, analysis and diagrams related to the heat transfer process of the pertinent components of the existing food cooking device, explanations and conclusions (Due: Week 6).

- Company Report on Potentiometer Design and Testing: Each group of five students (Due: Week 8)

Written laboratory report format:

- Use Microsoft Word software to type the laboratory reports;
  - Use appropriate tables and graphs if needed to create concept maps and other visual elements, to illustrate answers to the four essential questions (graphs can be created in Microsoft Word or Excel);
  - Use Microsoft Word Equation Editor tool to type formulas;
  - Include digital pictures and scanned sketches to be done on engineering notebook if related;
  - Include website links to relevant information (documents, videos, audios, etc.) found in the Internet if needed.
- Use PowerPoint software to create a 10-slided presentation based on the Written Laboratory Report, as a tool for presenting the findings to the class.

Teacher-Directed Evidence (i.e., Quizzes/Tests and Prompts)	Quizzes: At the end of each Mini Lesson, a multiple-choice and true/false quiz will be given (10-20 questions, 20 minutes). The content will be the most important principles of science, engineering, art, technology and design covered in each Mini Lesson. Final Exam: At the end of the course, a final exam will be given (20

	multiple-choice and true/false question, plus 2 worked-out problems on electrical laws. Formulas will be provided).
Observations (What will be observed and recorded?)	Observations, critique and tutoring: • Student participation in group discussion and presentation; • Student behavior in engineering analysis and design process; • Student observance of classroom disciplines (lecture attendance, homework turn-ins, etc.)

A-II-B. Possible and Acceptable Media and Materials

Content Media	In addition to textbooks to be used (*Figure 1B*, p. 27), other media including videos, audiotapes, CD-ROMs, and World Wide Web resources will be used. These auxiliary instructional materials will be found from the Internet source listed in Chapter 9, p. 168).
Instructional Materials	The following instructional materials will be used: • Sample food cooking devices (*Figure 2A*, pp. 40-43); • Electronics Workbench and Granta Materials Intelligence software programs; • Breadboard and other electrical/electronics components; • Equipment used to convey concepts, ideas, or principles, such as whiteboard, PowerPoint presentation, graphs and charts.

A-II-C. Possible and Acceptable Teaching Methods

Presentation Formats	Information will be presented to learners through: 1. Lectures; 2. Discussions after the lecture; 3. Demonstrations in lab and in classroom; 4. Individual tutoring during the instructor's office hour. Instruments for evaluating the effectiveness of each format during and after its delivery: A student representative will be assigned to collect anonymous student feedbacks on each of the above four methods of delivery, and to transmit these anonymous feedbacks to the instructor, including: (1) positive and negative comments; and (2) suggestions. Surveys on instructor performance (based on the above feedbacks and suggestions) will be conducted at the mid term and finals.
Scaffolding Strategies	The following scaffolding instruments will be used: • Advanced Organizers (Principles and Formula Sheets, Important Things to Remember Sheets, etc.); • Cues (with everyday analogy);

	• Advanced distribution (in multiple formats) of key vocabulary; • Coaching and tutoring; • Student tutoring each other.
Methods of Emphasizing critical information and relationships	Methods for supporting students in identifying and grasping critical information and relationships: • Explaining scientific principles with as plain and as everyday English as possible; • Repeating, re-wording, and re-phrasing; • Raising the voice during the lecture when mentioning important concepts and ideas; • Using physical gestures, such as pointing, and highlighting; • Using multiple examples for teaching the same concept; • Pausing and inviting questions; • Reviewing the most important principles, ideas, formulas, etc..
Flexible Groupings and Peer Support	Learners will be mature students in the senior/graduation years, who need more coaching than teaching; since the design process will involve extensive team work, peer support will be vital. Accordingly, flexible groupings will include: • Activities of Mini Lessons. Groups of four to five students will be working in (1) lab experiment; (2) design activities; (3) home works; • Diversity of instructional methods: (1) Lecture to whole class; (2) tutoring to groups of students with similar questions; and (3) tutoring to individual students with particular questions.
Methods of Providing descriptive feedback	Descriptive Feedback will include: • Discussion with students in groups or as individuals over their homework assignment and design project (personal communication); • Provide samples of design by former students; • Provide templates for writings (lab report, reflection paper, etc.); • Explain design criteria with students; • Ask students to compare and contrast their products and performances with design samples and criteria; • Require students to review one another's work before submission; • Give a critique after the presentation of each student. Evaluative feedback will include: • Percentage or a letter grade with short comments on student quizzes.

Chapter 2: Overview About the Engineering Design Challenge Scenario

This engineering design capstone experience will provide students with an opportunity to (1) conduct a market research (through Internet search and store visitations, etc.); (2) study real world engineering design through reverse engineering activities; (3) consolidate previously learned principles of physics, chemistry, math, arts and economics by applying them to the re-design of a real world product; (3) deepen understanding of previously learned topics by exploring more detailed and specific information.

Available Food Cooking Devices Found in Major Chain Stores

Figure 2A shows some samples of available food cooking devices found from the Website of Sears/K-Mart (http://www.sears.com) and Wal-Mart (http://www.walmart.com). Products featured are those that are preliminarily considered as (1) offering multiple functions; (2) reasonably priced; and (3) convenient to use. Since market conditions are changing continuously, updates to the market data should be made so as to keep up with the real world situation in engineering and product design.

A. Nesco 5 Quart Double Decker Food Steamer - 2 Trays, 60 Minute Timer
$28.99
http://www.sears.com/shc/s/p_10153_12605_00880802000P?keyword=slow+cooker

B. Hamilton Beach 3-in-1 Slow Cooker
$59.99
http://www.sears.com/shc/s/p_10153_12605_00813434000P?keyword=slow+cooker

C. Panasonic 10 Cup Rice Cooker / Steamer
$75.99
http://www.sears.com/shc/s/p_10153_12605_00888513000P?keyword=Panasonic+10+Cup+Rice+Cooker+/+Steamer

Figure 2A. Food cooking devices proposed for reverse engineering exercise.

D. Deni 3 qt. Slow Cooker/Deep Fryer
$96.99
http://www.sears.com/shc/s/p_10153_12605_00849501000P?keyword=slow+cooker

E. Continental Platinum 4-Slice Stainless Steel & Black Toaster
$29.99
http://www.sears.com/shc/s/p_10153_12605_00896518000P?keyword=toaster#desc

F. Nesco Professional 6 qt. Digital 3-in-1 Pressure Cooker
$129.99
http://www.sears.com/shc/s/p_10153_12605_00897382000P?keyword=slow+cooker

G. Deni 3 Tier Food Steamer
$ 39.99
http://www.kmart.com/shc/s/p_10151_10104_011W704799350001P?vName=Appliances&cName=Small%20Kitchen%20Appliances&sName=Slow%20Cookers%20&%20Steamers&sid=K-on-Sx20k061224x0000002#crumbWrapper

H. Kalorik 700 Watt Combi Sandwich/Grill/Waffle Maker
$69.99
http://www.sears.com/shc/s/p_10153_12605_00897951000P?keyword=waffle+maker

I. Chef's Choice Waffle/Cone Express™ Waffle Cone Maker
$62.99
http://www.sears.com/shc/s/p_10153_12605_00870015000P?keyword=waffle+maker

Figure 2A. Continued.

J. Nostalgia Electrics Old Fashioned Hot Dog Roller Grill/Griddle
$59.99
http://www.sears.com/shc/s/p_10153_12605_00897759000P?keyword=electric+griddle

K. West Bend Breadmaker
$145.99
http://www.sears.com/shc/s/p_10153_12605_00888155000P?keyword=waffle+maker

L. Black & Decker Extra Large Electric Skillet with Glass Lid
$ 36.99
http://www.kmart.com/shc/s/p_10151_10104_011W972628110001P?vName=Appliances&cName=Small%20Kitchen%20Appliances&sName=Griddles%20&%20Grills&sid=K-on-Sx20k061224x0000002#descriptionAnchor

M. Kenmore Water-Pumping Coffeemaker
$10.99
http://www.sears.com/shc/s/p_10153_12605_05235180000P?keyword=coffee+maker

N. National Presto PowerCrisp" microwave bacon cooker
$18.99
http://www.sears.com/shc/s/p_10153_12605_00880731000P?keyword=egg+cooker

O. Krups Egg Express Cooker
$29.99
http://www.sears.com/shc/s/p_10153_12605_00848643000P?keyword=egg+cooker#desc

Figure 2A. Continued.

P. Back to Basics 6 Quart Stir Crazy Corn Popper
$ 34.99
http://www.kmart.com/shc/s/p_10151_10104_011W838978110001P?vName=Appliances&cName=Small%20Kitchen%20Appliances&sName=Entertaining&sid=K-on-Sx20k061224x0000002

Q. Aroma 5-Tier Rotating Food Dehydrator
$34.98
http://www.walmart.com/catalog/product.do?product_id=5871078#ProductDetail

R. George Foreman's G5 Grill with 5 Interchangeable Plates
$99.44
http://www.walmart.com/catalog/product.do?product_id=4790227

S. Back to Basics Egg & Muffin 2 Slice Toaster, TEM500 $29.88
http://www.walmart.com/catalog/product.do?product_id=3999075

T. Presto Pizzazz Pizza Oven
$39.96
http://www.walmart.com/catalog/product.do?product_id=3218

U. Salton Santa Fe Quesadilla Maker
$19.98
http://www.walmart.com/catalog/product.do?product_id=5639871

V. Old-Fashioned Hot Dog Roller with Griddle
$29.92
http://www.walmart.com/catalog/product.do?product_id=5715284

W. Aroma 5-Quart Electric Wok
$49.88
http://www.walmart.com/catalog/product.do?product_id=5871069

X. Aroma Single-Burner Portable Electric Range Hot Plate
$18.88
http://www.walmart.com/catalog/product.do?product_id=5871070

Figure 2A. Continued.

Possibility for Better Design Solutions

Basic understanding of the existing products: All of the above food cooking devices (*Figure 2A*) share the following components: (1) a power plug to be inserted into a 220-V power outlet; (2) an electro-thermal converter that change electrical energy into thermal energy (with variable temperature) for cooking tasks; (3) a food container (in metal, glass, ceramic, or plastic); and (4) a metal heat transfer interface that connect the electro-thermal converter with the food container (see *Figure 2B* below).

Basic strategy for re-design: Therefore, it is possible to design: (1) a master electro-thermal converter with various temperature settings using a potentiometer; (2) various food container attachments for performing various food cooking tasks; and (3) a master metal heat transfer interface that connect the electro-thermal converter with various food container attachments.

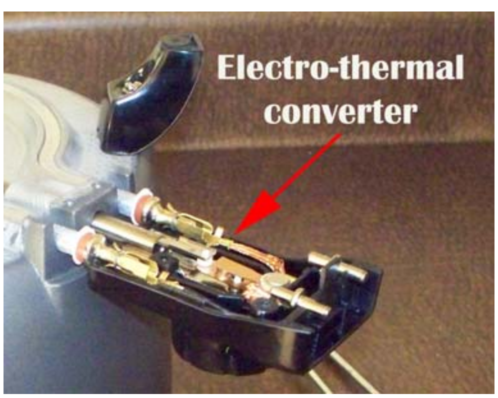


Figure 2B. Typical components of a food cooking device.

Objective of the re-design: A Multifunctional Food Cooker. This device should be able to perform the various related but different functions currently performed by various products in the market place, including but not limited to rice cooker, vegetable steamer, toast maker, slow cooker, electrical pan, electrical wok, cookie maker, bread maker, and others (see *Figure 2A*).

Desirability of the re-design: Designing and manufacturing multi-functional products offer the benefits of (1) saving the Earth's limited resources by combining similar components common to various products into one master component (such as the potentiometer used in many food cooking appliances, or electric motors used in various food cutting devices, etc.); (2) saving consumers total purchasing cost for a variety of related products; (3) allowing manufacturers to enhance corporate image as ecologically conscious and consumer-centered corporate citizens; and (4) offering potentials of long-term and sustainable profit for manufacturers with decreased consumption of the Earth's limited resource. In fact, many food cooking appliance manufacturers are already engaged in this direction:

- Panasonic 10 Cup Rice Cooker/Steamer: This $75.99 appliance combines a rice cooker and a streamer (*Figure 2A- C*).
- Deni 3 qt. Slow Cooker/Deep Fryer: This $96.99 appliance combines a slow cooker and a deep fryer (*Figure 2A-D*).
- Kalorik 700 Watt Combi Sandwich/Grill/Waffle Maker: This $69.99 appliance combines a Sandwich maker, a grill maker, and a waffle maker (*Figure 2A-H*).
- Chef's Choice Waffle/Cone Express™ Waffle Cone Maker: This $62.99 appliance combines a waffle maker and a cone maker (*Figure 2A-I*).
- George Foreman's G5 Grill with 5 Interchangeable Plates: This $99.44 appliance is a multi-functional grill (*Figure 2A-R*).

Feasibility of the re-design: Consultation has been made with Dr. John Mativo, Professor of Engineering at the College of Education, the University of Georgia on the feasibility of the designing a multi-functional food cooking appliance with (1) a master potentiometer; (2) a master electro-thermal interface; and (3) a variety of food cooking container attachments. This is basically a physics problem involving electrical circuit analysis and heat transfer. Other branches of STEM (material selection and manufacturing) and non-STEM academic subjects (industrial product design, and design aesthetics) could be included to make this Engineering Design Challenge multidisciplinary, similar to the Animatronics Project developed by Dr. Mativo and other at the Ohio Northern University (2005).

Chapter 3:
The Design Challenge

The Challenge

As mentioned at the end of Chapter 2, designing a Multifunctional Food Cooker with (1) a master potentiometer with variable temperature settings; (2) a master electro-thermal interface; and (3) a variety of food cooking container attachments is the theme of this Engineering Design Challenge. The end result of this project will be a fully-functional working prototype and other professional design presentation materials. This new appliance should be able to perform the various related but different functions currently performed by various products in the market place, including but not limited to rice cooker, vegetable steamer, toast maker, slow cooker, electrical pan, electrical wok, cookie maker, bread maker, and others.

Time Requirements

Before starting this Engineering Design Challenge with your students, allow time to carefully read this guide. Allow several hours to gather and prepare the materials your students will need for the challenge, and about one half-hour to conduct reverse engineering activities, including but not limited to: (1) disassemble a few existing food cooking appliances, obtain pertinent data from the packaging and the component labels, analyze the functions of different component, make measurements and calculations; and (2) design, simulate, built and test a potentiometer with a large range of resistance and current settings.

It is possible for your students to engage in the major part of this Engineering Design Challenge (Mini Lesson A), to experience the design process within the span of five or six class sessions, and to come up with a functional design and fabrication of a new potentiometer and the electro-thermal interface, plus designing a few food cooking container attachments within 6 weeks maximum. Next, the Engineering Design Challenge can be extended into a multi-functional product design project, which is multidisciplinary, “system thinking,” and real-world-oriented, involving other branches of STEM and non-STEM activities (Mini Lesson B through E).

During the challenge, with appropriate guidance from the instructors, students will have enough time to analyze data, conduct engineering predictive analysis, design a real product and improve their design as their gradually incorporate principles and skills covered beyond the major part of this Engineering Design Challenge (Mini Lesson A).

Materials and Cost Estimates

The materials you will need to build the prototype in this Engineering Design Challenge are very simple and easy to acquire.

Need:

For the Potentiometer: Much of what you need (i.e., wires, resistors, digital multi-meter, etc.) you can get from the school's physics laboratory, or a local branch of RadioShack store, or any other electronics component suppliers (such as online stores or retailers via catalog). Alternatively, components from existing food cooking devices can be recycled (see *Figures 3A* and *3B* for relevant devices).

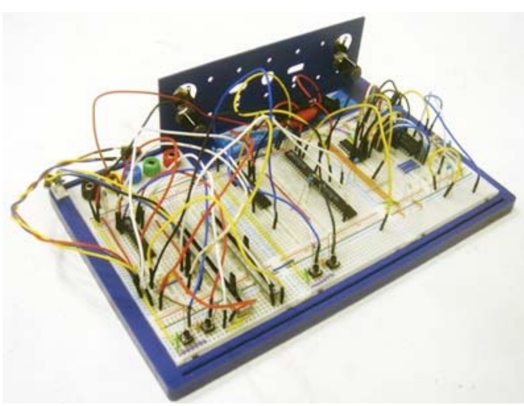
For the Electro-thermal interface: Metal materials needed for this component are either available from your school's manufacturing lab, or can be purchased from material suppliers from local, online or catalog retailers.

For the Food cooking container attachments: Metal, plastic, and ceramic materials needed for this component are either available from your school's manufacturing lab, or can be purchased from material suppliers from local, online or catalog retailers.

Cost:

The electronics components and metal, plastic, and ceramic materials, plus measuring and testing devices you may need to purchase will greatly influence your costs, and that in turn will depend on what you presently have available to you in your classroom or school's lab facilities. If not already available (which is unlikely), the cost for the electronics components will be approximately $50 maximum; and the cost for the metal, plastic, and ceramic materials will be approximately $50 maximum. These electronics components are usually very cheap (see *Figure 3C* and *Figure 3D*).

In addition to the above, samples of existing food cooking appliances are needed. For possible cost of acquiring them, refer to Chapter 5 (Table 5A, pp. 65-65).



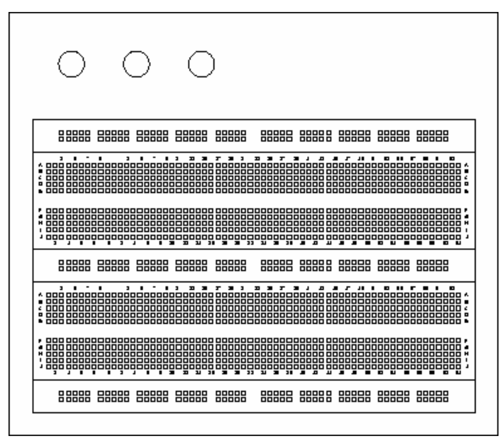
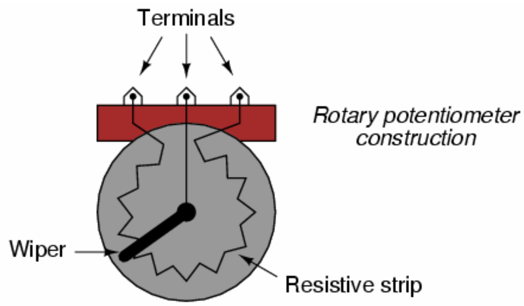
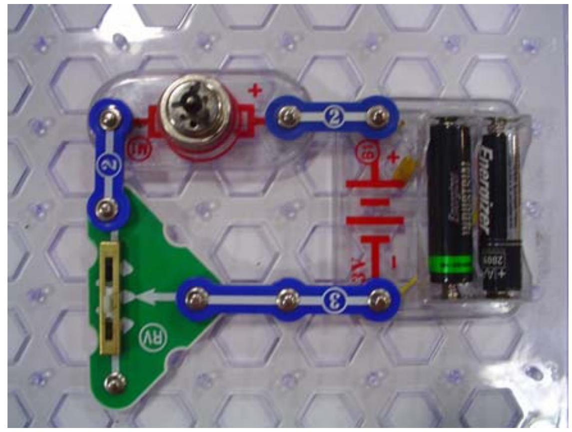


Figure 3A. Breadboard (Source: Google Image Search at http://images.google.com/).





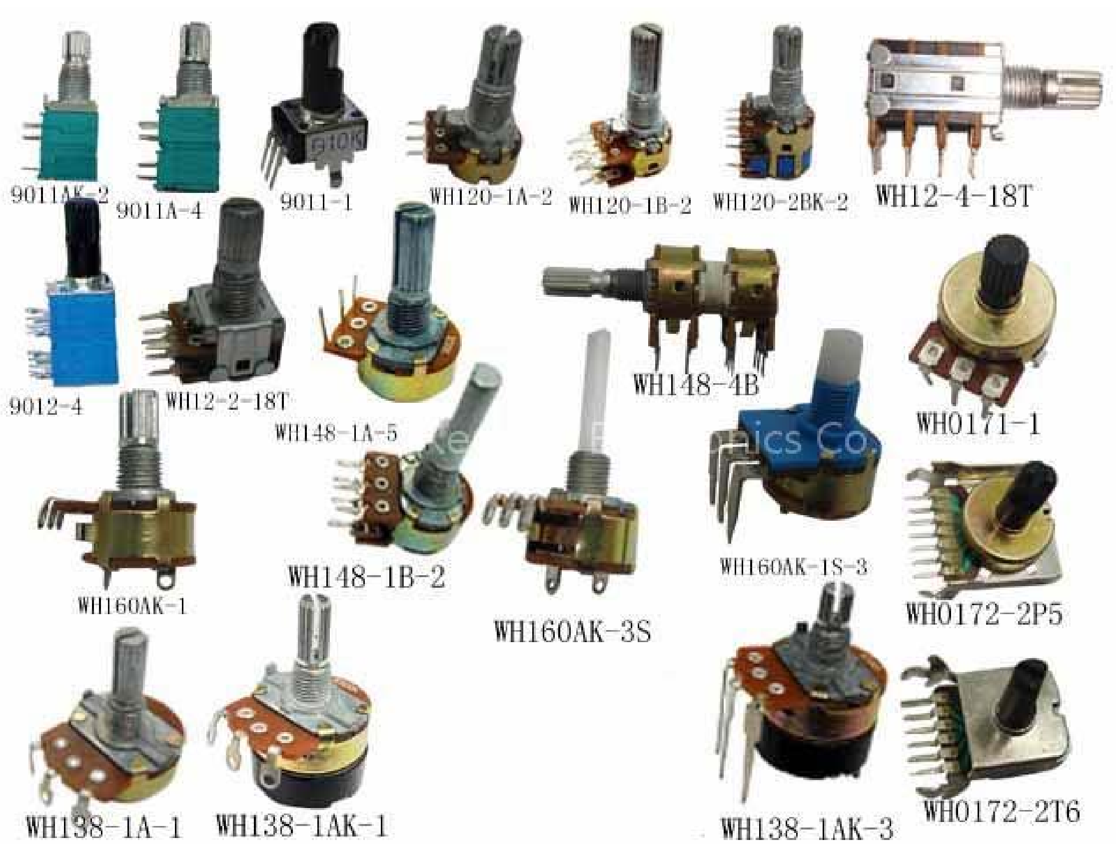


Figure 3B. Examples of potentiometers (Source: Google Image Search at http://images.google.com/).

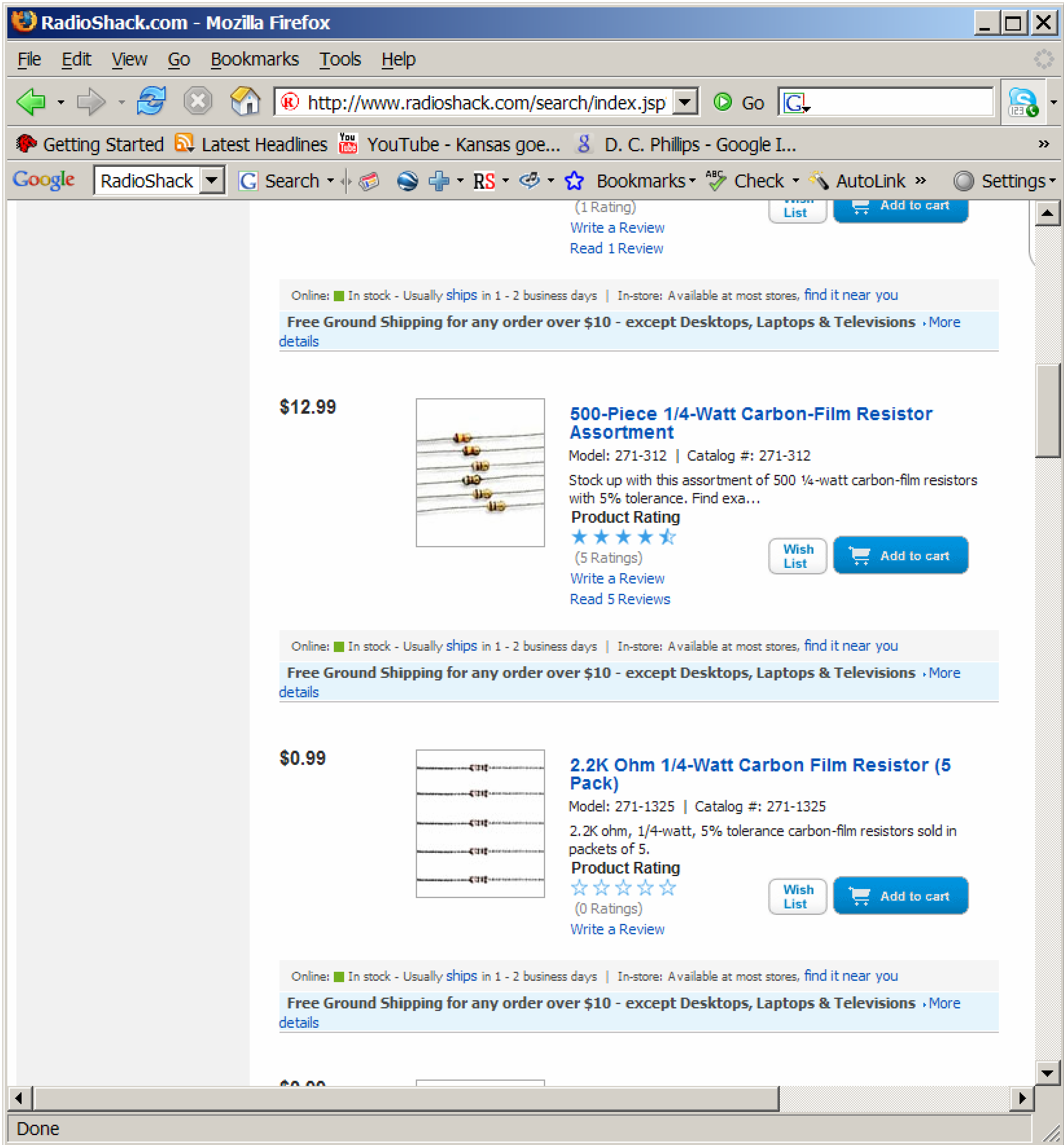


Figure 3C. Costs of resistors from RadioShack website at http://www.radioshack.com/search/index.jsp?kw=resistor&origkw=resistor

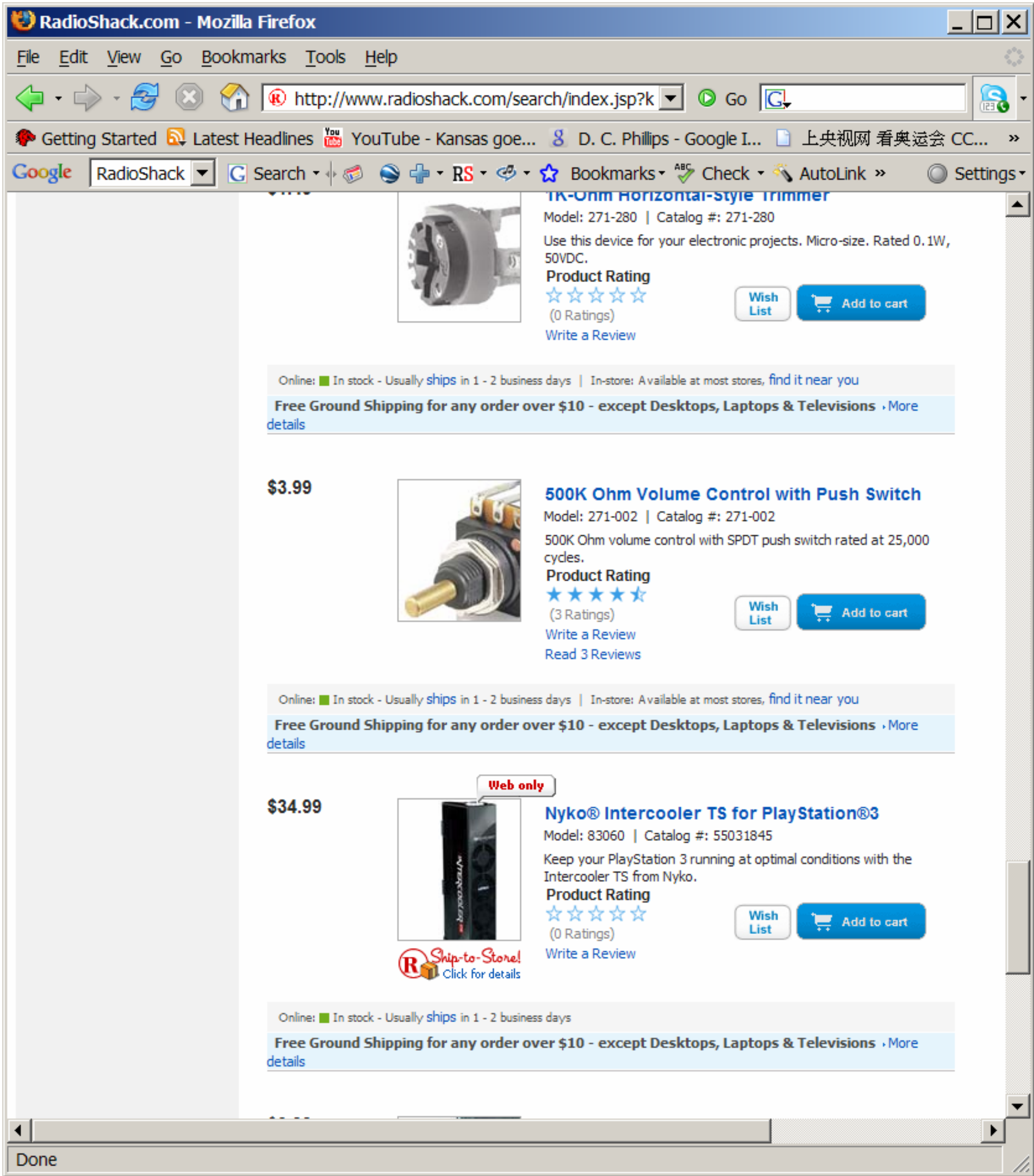


Figure 3D. Costs of potentiometer from RadioShack website at http://www.radioshack.com/search/index.jsp?kw=potentiometer&origkw=potentiometer

Prototyping Cost Estimates

According to Dr. John Mativo, the University of Georgia Driftmier Engineering Center has prototyping equipment; and CNC prototyping facilities outside of schools usually charge $25.00 per hour in addition to material cost. Thus, The CNC prototyping hourly fee might be up to $500.00 (the actual cost will depend on the complexity of the components' shapes. School facilities should be utilized as much as possible.

An Inquiry-based Challenge

The multi-functional Food Cooker Engineering Design Callenge engages students in a real-world, hands-on scientific inquiry. Participants will propose designs of (1) a master potentiometer; (2) a master electro-thermal interface; and (3) a variety of food cooking container attachments; test them, make observations, collect data, and collaborate as they analyze results and attempt to identify the best design solutions to adopt. Based on their analysis and on study of existing product samples they will make modifications to their model and repeat the process in an effort to produce the most effective and multi-functional Food Cooker possible. Ultimately, they will communicate their results to the larger community (other schools and corporations).

Phases of Learning Module (Mini Lessons)

The following three main phases of the engineering design challenge learning module, as defined by the criteria for the development of this project, will be used. The relationship among the three main phases is illustrated in *Figure 2*.

1. Conceptualize:

    - Identify problem, materials & constraints (based on market research and reverse engineering, as well as knowledge content from Mini Lesson 2 - Heat Transfer, and Mini Lesson 3 - Materials Science)

    - Brainstorm ideas and possible solutions (using NCETE High School Engineering Design Process, see *Figure 2*)

2. Construct & Test;

    - Select a solution (based on a synthetic analysis of all relevant factors combined, such as functions, cost, etc., using knowledge content from Mini Lesson E - Manufacturing and Engineering Economics, etc.)

    - Design and Construct (using knowledge and skills from Mini Lesson D – Industrial Product Design, and Mini Lesson E - Arts, Design and Fabrication, etc., including CAD modeling and drafting)

    - Prototype (using knowledge and skills from Mini Lesson D – Industrial Product Design, and Mini Lesson E - Arts, Design and Fabrication, etc.. Fully functional physical prototypes will be built by each team using university manufacturing or fabrication facilities)

    - Redesign or modify

- Retest (fully functional physical prototypes will be tested by each team using university testing facilities)

3. Acquire Knowledge:

- Research (through: a. store visitation; 2. consumer survey; 3. Internet search including patent search; and 4. library search)
- Share solutions (through brainstorming meeting, group discussions, etc.)
- Reflect and discuss (through brainstorming meeting, group discussions, consultation with instructors, etc.)

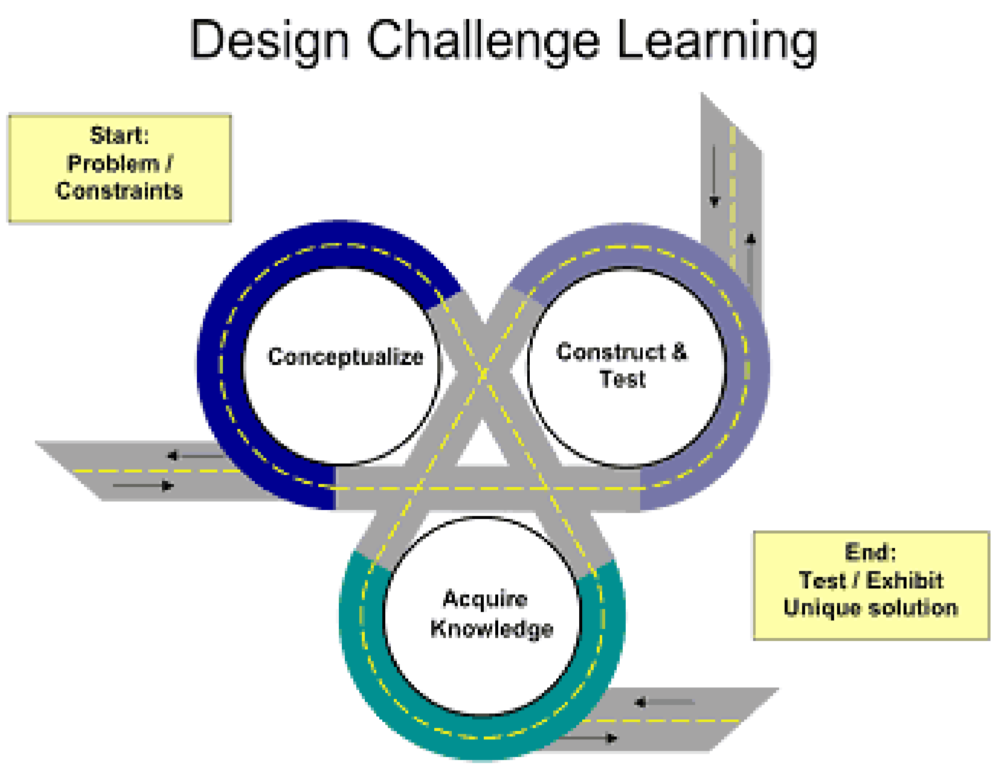


Figure 3A. The relationship among the three main phases (Source: NCETE Core 4 Course Materials, available at http://bb.usu.edu).

Pedagogy

Figure 3B represents an interpretation of the *NCETE High School Engineering Design Process*, a generic engineering design pedagogy, to be used in this project. Student teams and instructors do not have to follow a linear path from problem to solution, but rather a recursive one that often changes the orders of conceptualizing, constructing and testing, and acquiring knowledge, all the while applying multiple engineering and product design principles, skills and creative mental process of innovators.

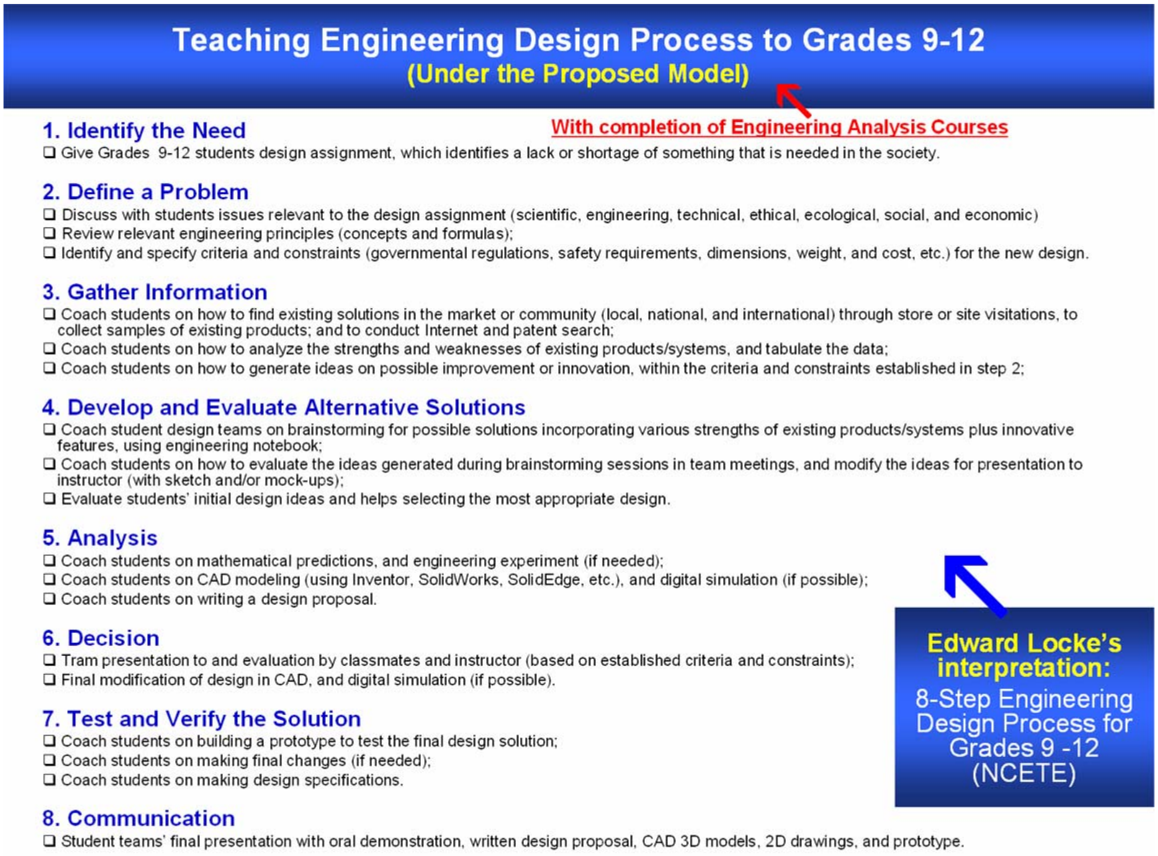


Figure 3B. NCETE High School Engineering Design Process
(Edward Locke's Interpretation)

Chapter 4:
Connections to National Curriculum Standards

This Engineering Design Challenge is in compliance with the following national standards for Grades 9-12:

- *Principles and Standards for School Mathematics*: Published by National Council of Teachers of Mathematics (NCTM, 2004), available from http://standards.nctm.org/document/appendix/numb.htm (*Figure 4A*).

- *National Science Education Standards* (*Chapter 6 - Science Content Standards)*: Published by National Research Council (NRC, 1996, *Figure 4B*). http://www.nap.edu/openbook.php?record_id=4962&page=103

- *Standards for Technological Literacy (Content for the Study of Technology)*: Published by International Technology Education Association (ITEA, 2002), available from ITEA Website at http://www.iteaconnect.org/TAA/Publications/TAA_Publications.html (*Figure 4C*).

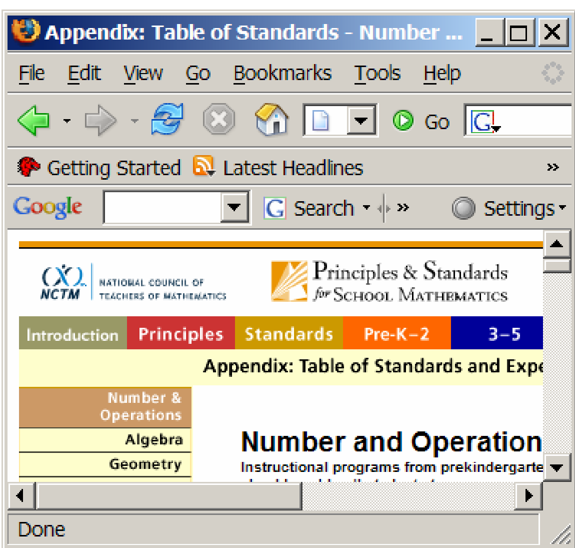


Figure4A. Principles and Standards for School Mathematics.

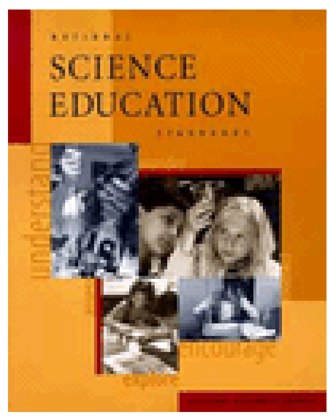


Figure 4B. National Science Education Standards.

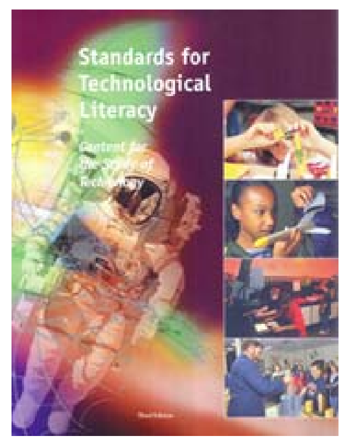


Figure 4C. Standards for Technological Literacy (Content for the Study of Technology)

Connections with National Council of Teachers of Mathematics' Connections to Principles and Standards for School Mathematics

Standard: Grades 9-12	Engineering Design Challenge Connections	Check
Number and Operations Standard		✓
• Develop a deeper understanding of very large and very small numbers and of various representations of them;	• Mini Lesson A (Physics for Scientist and Engineers - Electricity and Heat Transfer): Computations and estimates (circuit analysis, heat transfer, surface areas, etc.).	✓
Understand meanings of operations and how they relate to one another		✓
• Judge the effects of such operations as multiplication, division, and computing powers and roots on the magnitudes of quantities;	• Mini Lesson A (Physics for Scientist and Engineers - Electricity and Heat Transfer): Computations and estimates (circuit analysis, heat transfer, surface areas, etc.). • Mini Lesson C (Design Aesthetics and Graphic Presentation): Computations and estimates (volumes of 3D bodies and surface areas).	✓
Compute fluently and make reasonable estimates		✓
• Develop fluency in operations with real numbers, vectors, and matrices, using mental computation or paper-and-pencil calculations for simple cases and technology for more-complicated cases.	• Mini Lesson A (Physics for Scientist and Engineers - Electricity and Heat Transfer): Computations and estimates (circuit analysis, heat transfer, surface areas, etc.). • Mini Lesson C (Design Aesthetics and Graphic Presentation): Computations and estimates (volumes of 3D bodies and surface areas). • Mini Lesson E (Manufacturing and Engineering Economics): Computations and estimates (Break-Even Chart).	✓
• Judge the reasonableness of numerical computations and their results.		✓

Connection with National Research Council's National Science Education Standards (Chapter 6 Science Content Standards)

Standard: Grades 9-12	Engineering Design Challenge Connections	Check
Science as Inquiry Standards		✓
• Abilities necessary to do scientific inquiry;	• Mini Lesson A (Physics for Scientist and Engineers - Electricity and Heat Transfer): Reviewing physics subjects and find additional information through Internet. • Mini Lesson B (Material Selection): Finding materials information and locating suppliers through Internet search. • Mini Lesson E (Manufacturing and Engineering Economics): Studying modern manufacturing technology through Internet search and video watching.	✓
• Understanding about scientific inquiry.		✓
Physical Science, Life Science, and Earth and Space Science Standards		✓
• Structure of atoms;	• Mini Lesson B (Material Selection): Review materials properties, chemical structure and reaction causing changes in properties.	✓
• Structure and properties of matter;		✓
• Chemical reactions;		✓
• Motions and forces;	• Mini Lesson A (Physics for Scientist and Engineers - Electricity and Heat Transfer): Review of electro-thermal energy conversion, electron motion in the circuit, Ohm's law, etc.	✓
• Conservation of energy and increase in disorder;		✓
• Interactions of energy and matter.		✓
Science and Technology Standards		✓
• Abilities of technological design	• Mini Lesson A (Physics for Scientist and Engineers - Electricity and Heat Transfer): Design, fabrication and testing of a potentiometer with multiple current and resistance settings. • Mini Lesson D (Industrial Product Design): Applying scientific principles to real-world technological design.	✓ ✓
• Understanding about science and technology	• Mini Lesson B (Material Selection): Understanding the properties of different types of engineering materials and their application in engineering design. • Mini Lesson E (Manufacturing and Engineering Economics): Computations and estimates (Break-Even Chart).	✓

Connections with ITEA Standards for Technological Literacy (Content for the Study of Technology), 2002

Standard: Grades 9-12	Engineering Design Challenge Connections	Check
The Nature of Technology		
Standard 1. Students will develop an understanding of the characteristics and scope of technology. (p. 23, p. 31)		✓
J. The nature and development of technological knowledge and processes are functions of the setting.	• Mini Lesson E (Manufacturing and Engineering Economics): Evolution of manufacturing technology throughout history and across cultures.	✓
K. The rate of technological development and diffusion is increasing rapidly.	• Mini Lesson E (Manufacturing and Engineering Economics): Rapid advance of Robotics-based CNC manufacturing technology in the Age of Digital Revolution.	✓
L. Inventions and innovations are the results of specific, goal-directed research.	• Mini Lesson D (Industrial Product Design): Design serves specific social needs within the society's cultural values.	✓
M. Most development of technologies these days is driven by the profit motive and the market.	• Mini Lesson D (Industrial Product Design): Balance between short-term and long-term profit potentials.	✓
Standard 2. Students will develop an understanding of the core concepts of technology. (p. 32, pp. 42-43)		✓
W. Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems.	This Engineering Design Challenge is interdisciplinary and offers an opportunity for students to integrate "Analytic Reduction" and "System Thinking" models of engineering design process. It include 5 Mini Lessons: • Mini Lesson A (Physics for Scientist and Engineers - Electricity and Heat Transfer); • Mini Lesson B (Material Selection); • Mini Lesson C (Design Aesthetics and Graphic Presentation); • Mini Lesson D (Industrial Product Design); • Mini Lesson E (Manufacturing and Engineering Economics)..	✓
X. Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems.		✓
Y. The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.		✓
Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.		✓
AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.		✓
BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.		✓

Standard: Grades 9-12	Engineering Design Challenge Connections	Check
Standard 3. Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study. (p. 44, pp. 51-52)		✓
G. Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function.	• Mini Lesson A (Physics for Scientist and Engineers - Electricity and Heat Transfer): Reverse engineering allows the positive features of existing design to be recycled while the negative ones be discarded. • Mini Lesson D (Industrial Product Design): Interdisciplinary approach promotes holistic design solution.	✓
H. Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields.		✓
I. Technological ideas are sometimes protected through the process of patenting.	• Mini Lesson D (Industrial Product Design): Patent application introduced.	✓
J. Technological progress promotes the advancement of science and mathematics.	• Mini Lesson A (Physics for Scientist and Engineers - Electricity and Heat Transfer): ElectronicsWorkbench digital simulation confirms the results of analytic computations before prototyping. • Mini Lesson B (Material Selection): Finding materials information with Granta Materials Intelligence shortens design time. • Mini Lesson D (Industrial Product Design) and Mini Lesson E (Manufacturing and Engineering Economics): 3D modeling with CAD streamlines prototyping and manufacturing.	✓
Technology and Society		
Standard 4. Students will develop an understanding of the cultural, social, economic, and political effects of technology. (p.57, pp. 62-63)		✓
I. Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.	• Mini Lesson E (Manufacturing and Engineering Economics): Good design practice corresponds to available manufacturing technology and to cost effectiveness.	✓
J. Ethical considerations are important in the development, selection, and use of technologies.	• Mini Lesson B (Material Selection): Material usage should be ecologically sustainable. • Mini Lesson D (Industrial Product Design): Good product design should serve user needs and help to protect the environment.	✓
K. The transfer of a technology from one society to another can cause cultural, social, economic, and political changes affecting both societies to varying degrees.		✓

Standard: Grades 9-12	Engineering Design Challenge Connections	Check
Standard 5. Students will develop an understanding of the effects of technology on the environment. (p. 65, pp. 71-72)		✓
G. Humans can devise technologies to conserve water, soil, and energy through such techniques as reusing, reducing, and recycling.	• Mini Lesson B (Material Selection): Material usage should be ecologically sustainable. • Mini Lesson D (Industrial Product Design): Good product design should serve user needs and help to protect the environment.	✓
H. When new technologies are developed to reduce the use of resources, considerations of trade-offs are important.		✓
L. Decisions regarding the implementation of technologies involve the weighing of trade-offs between predicted positive and negative effects on the environment.		✓
Standard 6. Students will develop an understanding of the role of society in the development and use of technology. (p. 73, 78)		✓
H. Different cultures develop their own technologies to satisfy their individual and shared needs, wants, and values.	• Mini Lesson B (Material Selection): Development of new materials evolves over time to serve increased human needs. • Mini Lesson E (Manufacturing and Engineering Economics): Advance in manufacturing technology corresponds to improvements in socio-economic conditions.	✓
I. The decision whether to develop a technology is influenced by societal opinions and demands, in addition to corporate cultures.		✓
J. A number of different factors, such as advertising, the strength of the economy, the goals of a company, and the latest fads contribute to shaping the design of and demand for various technologies.		✓

<table>
<tr><th>Standard: Grades 9-12</th><th>Engineering Design Challenge Connections</th><th>Check</th></tr>
<tr><td colspan="2">Standard 7. Students will develop an understanding of the influence of technology on history. (p. 79, pp. 85-87)</td><td>✓</td></tr>
<tr><td>G. Most technological development has been evolutionary, the result of a series of refinements to a basic invention.</td><td rowspan="6"><u>Mini Lesson A (Physics for Scientist and Engineers - Electricity and Heat Transfer)</u>: New design is usually an innovative re-design (reverse engineering, combination, permutation, decomposition and recombination, and transposition of diverse existing and new ideas.
<u>Mini Lesson B (Material Selection)</u>: Development of materials corresponds to evolution of socio-economic conditions.
<u>Mini Lesson C (Design Aesthetics and Graphic Presentation)</u>: Aesthetics is a product of changing cultural and natural conditions.
<u>Mini Lesson D (Industrial Product Design)</u>: Industrial product design as a specialized human career is a product of Industrial Revolution.
<u>Mini Lesson E (Manufacturing and Engineering Economics)</u>: Manufacturing technology advances with the advances of other branches of science and technology.</td><td>✓</td></tr>
<tr><td>H. The evolution of civilization has been directly affected by, and has in turn affected, the development and use of tools and materials.</td><td>✓</td></tr>
<tr><td>I. Throughout history, technology has been a powerful force in reshaping the social, cultural, political, and economic landscape.</td><td>✓</td></tr>
<tr><td>J. Early in the history of technology, the development of many tools and machines was based not on scientific knowledge but on technological know-how.</td><td>✓</td></tr>
<tr><td>N. The Industrial Revolution saw the development of continuous manufacturing, sophisticated transportation and communication systems, advanced construction practices, and improved education and leisure time.</td><td>✓</td></tr>
<tr><td>O. The Information Age places emphasis on the processing and exchange of information.</td><td>✓</td></tr>
<tr><td colspan="3">Design</td></tr>
<tr><td colspan="2">Standard 8. Students will develop an understanding of the attributes of design. (p. 91, pp. 97-98)</td><td>✓</td></tr>
<tr><td>H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.</td><td>Student collaboration throughout all Mini Lessons (including brainstorming, researching and generating ideas, identifying criteria and specifying constraints, and all other activities).</td><td>✓</td></tr>
<tr><td>I. Design problems are seldom presented in a clearly defined form.</td><td>This Engineering Design Challenge is
Open-ended; and
“System Thinking.”</td><td>✓</td></tr>
<tr><td>J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.</td><td>Throughout all Mini Lessons:
Student discussions in groups;
Instructor coaching and critique.</td><td>✓</td></tr>
<tr><td>K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.</td><td><u>Mini Lesson D (Industrial Product Design)</u>: Explanation of the idea of trade-offs.</td><td>✓</td></tr>
</table>

Standard: Grades 9-12	Engineering Design Challenge Connections	Check
Standard 9. Students will develop an understanding of engineering design. (p. 99, pp. 104-105)		✓
I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.	• <u>Mini Lesson D (Industrial Product Design)</u>: Design principles and criteria established by the instructor (this guide). • <u>Mini Lesson E (Manufacturing and Engineering Economics)</u>: Prototyping and testing activities.	✓
J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.		✓
K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.		✓
Standard 10. Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving. (p. 106, pp. 111-112)		✓
I. Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.	• <u>Mini Lesson A (Physics for Scientist and Engineers - Electricity and Heat Transfer)</u>: Market research activity (Internet, store visitation, reverse engineering). • <u>Mini Lesson B (Material Selection)</u>: Internet search for materials suppliers. • <u>Mini Lesson D (Industrial Product Design)</u>: Research and development activities for a new product.	✓
J. Technological problems must be researched before they can be solved.		✓
K. Not all problems are technological, and not every problem can be solved using technology.	• <u>Mini Lesson C (Design Aesthetics and Graphic Presentation)</u>: Artistic and cultural values do have a place in engineering design. • <u>Mini Lesson D (Industrial Product Design)</u>: Ergonomics, ecologic and other non-technical factors do affect design.	✓
L. Many technological problems require a multidisciplinary approach.	• The whole Engineering Design Challenge is interdisciplinary.	✓

Standard: Grades 9-12	Engineering Design Challenge Connections	Check
Abilities for a Technological World		✓
Standard 11. Students will develop the abilities to apply the design process. (p. 115, p. 123-124)		✓
N. Identify criteria and constraints and determine how these will affect the design process.	All activities covered throughout the following Mini Lessons: • Mini Lesson A (Physics for Scientist and Engineers - Electricity and Heat Transfer). • Mini Lesson B (Material Selection). • Mini Lesson D (Industrial Product Design). • Mini Lesson E (Manufacturing and Engineering Economics).	✓
O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.		✓
P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.		✓
Q. Develop and produce a product or system using a design process.		✓
R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.		✓
Standard 13. Students will develop the abilities to assess the impact of products and systems. (p. 133, p. 138)		✓
J. Collect information and evaluate its quality.	All activities carried out through: • Mini Lesson A (Physics for Scientist and Engineers - Electricity and Heat Transfer). • Mini Lesson B (Material Selection). • Mini Lesson D (Industrial Product Design).	✓
K. Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and the environment.		✓
L. Use assessment techniques, such as trend analysis and experimentation, to make decisions about the future development of technology.		✓

Standard: Grades 9-12	Engineering Design Challenge Connections	Check
The Designed World		
Standard 19. Students will develop an understanding of and be able to select and use manufacturing technologies. (p. 182, pp. 189-190)		✓
M. Materials have different qualities and may be classified as natural, synthetic, or mixed.	• Mini Lesson B (Material Selection): Material properties and application covered.	✓
O. Manufacturing systems may be classified into types, such as customized production, batch production, and continuous production.	• Mini Lesson E (Manufacturing and Engineering Economics): All relevant topics covered.	✓
P. The interchangeability of parts increases the effectiveness of manufacturing processes.		✓
Q. Chemical technologies provide a means for humans to alter or modify materials and to produce chemical products.		✓
R. Marketing involves establishing a product's identity, conducting research on its potential, advertising it, distributing it, and selling it.	• Mini Lesson C (Design Aesthetics and Graphic Presentation): Company logo and product packaging design covered. • Mini Lesson E (Manufacturing and Engineering Economics): Marketing planning (Break-Even Chart) covered.	✓

Chapter 5:
Preparing to Teach

Detailed Materials Lists

The purpose of these Detailed Materials Lists is to identify everything the instructors will need to prepare in order to implement the Mini Lessons in this Engineering Design Challenge, beyond what the school's physics and manufacturing labs most likely can provide, such as electronics components and testing devices, or metal and plastic materials. Refer to Chapter 3 for estimated costs (pp. 45). In this Chapter, estimated costs are provided for items the instructors will need exclusively for this project and that are not likely to already be available in your classroom or school.

Purchase of sample products: The biggest cost is on the purchase of some existing food cooking appliances, to be used for the reverse engineering activity. The budget for purchasing these samples depends on your school's budget (a $500.00 maximum is recommended). The appliances listed in Table 5A are available at local WalMart, Sears and K-Mart stores, and are recommended for their (1) multi-functionality, (2) unique features, or (3) prices.

Free use of sample products: Some sample appliances can be donated or brought to school by students and instructors for reverse engineering activities and returned home (free use). Only the ones with components worth recycling need to be purchased (for a recommended maximum cost of $200.00).

Table 5A. Suggested List for Purchasing Existing Product Samples

Recommendation: Multi-functionality		
Name and Website	**Store**	**Price**
C. Panasonic 10 Cup Rice Cooker / Steamer http://www.sears.com/shc/s/p_10153_12605_00888513000P?keyword= Panasonic+10+Cup+Rice+Cooker+/+Steamer	Sears	$75.99
D. Deni 3 qt. Slow Cooker/Deep Fryer http://www.sears.com/shc/s/p_10153_12605_00849501000P?keyword=slow+cooker	Sears	$96.99
H. Kalorik 700 Watt Combi Sandwich/Grill/Waffle Maker http://www.sears.com/shc/s/p_10153_12605_00897951000P?keyword=waffle+maker	Sears	$69.99
I. Chef's Choice Waffle/Cone Express™ Waffle Cone Maker http://www.sears.com/shc/s/p_10153_12605_00870015000P?keyword=waffle+maker	Sears	$62.99
R. George Foreman's G5 Grill with 5 Interchangeable Plates http://www.walmart.com/catalog/product.do?product_id=4790227	WalMart	$99.44

Table 5A. Continued.

Recommendation: Unique Features		
T. Presto Pizzazz Pizza Oven http://www.walmart.com/catalog/product.do?product_id=3218	WalMart	$39.96
U. Salton Santa Fe Quesadilla Maker http://www.walmart.com/catalog/product.do?product_id=5639871	WalMart	$19.98
W. Aroma 5-Quart Electric Wok http://www.walmart.com/catalog/product.do?product_id=5871069	WalMart	$49.88
Q. Aroma 5-Tier Rotating Food Dehydrator http://www.walmart.com/catalog/product.do?product_id=5871078#ProductDetail	WalMart	$34.98
Recommendation: Prices		
O. Krups Egg Express Cooker http://www.sears.com/shc/s/p_10153_12605_00848643000P?keyword=egg+cooker#desc	Sears	$29.99
P. Back to Basics 6 Quart Stir Crazy Corn Popper http://www.kmart.com/shc/s/p_10151_10104_011W838978110001P?vName= Appliances&cName=Small%20Kitchen%20Appliances&sName= Entertaining&sid=K-on-Sx20k061224x0000002	K-Mart	$ 34.99
X. Aroma Single-Burner Portable Electric Range Hot Plate http://www.walmart.com/catalog/product.do?product_id=5871070	WalMart	$18.88
G. Deni 3 Tier Food Steamer http://www.kmart.com/shc/s/p_10151_10104_011W704799350001P?vName= Appliances&cName=Small%20Kitchen%20Appliances&sName= Slow%20Cookers%20&%20Steamers&sid=K-on- Sx20k061224x0000002#crumbWrapper	K-Mart	$39.99
L. Black & Decker Extra Large Electric Skillet with Glass Lid http://www.kmart.com/shc/s/p_10151_10104_011W972628110001P?vName= Appliances&cName=Small%20Kitchen%20Appliances&sName= Griddles%20&%20Grills&sid=K-on-Sx20k061224x0000002#descriptionAnchor	K-Mart	$ 36.99
M. Kenmore Water-Pumping Coffeemaker http://www.sears.com/shc/s/p_10153_12605_05235180000P?keyword=coffee+maker	Sears	$10.99
N. National Presto PowerCrisp" microwave bacon cooker http://www.sears.com/shc/s/p_10153_12605_00880731000P?keyword=egg+cooker	Sears	$18.99

Instructor Selection

The above Mini-Lessons will be taught by

- One engineering instructor: With background in mechanical and Electronics engineering (example: Dr. John Mativo, Professor of Engineering at the University of Georgia). This instructor can teach Mini Lessons A (Physics for Scientists and Engineers - Circuit Analysis and Heat Transfer), B (Material Selection) and E (Manufacturing and Engineering Economics).

- One art and design instructor: With background in digital arts and product design (example: Edward Locke, graduate student at the University of Georgia). This instructor can teach Mini Lessons C (Design Aesthetics and

Graphic Presentation) and D (Industrial Product Design). In addition, this instructor can help the engineering instructor to prepare teaching and learning materials for Mini Lessons B (Material Selection) and E (Manufacturing and Engineering Economics).

Similar format of interdisciplinary instructional collaboration explored in Mativo (2005) model will be used throughout this Engineering Design Challenge.

General Guidelines for Instructor Preparation

For the Mini Lesson A:

The Mini Lesson A (design of potentiometer, electro-thermal interface and food cooking container attachments) involves heavy-duty engineering analytic and predictive activities, although such activities is generally based on high school physics (taken before Grade 12, at around Grade 9) and electronics (taken sometimes as early as Grade 6). Instructors will make a sample design (with lab experiment write-ups, Engineering Notebook, etc.), to be shown to students, before the start of the semester. It might take up to three weeks to prepare for pedagogic materials related to this Mini Lesson (on a part-time basis so as to allow some recursive brainstorming, since this is an open-ended activity).

For all other Mini Lessons:

Mini Lessons B (Material Selection), C (Design Aesthetics and Graphic Presentation), n D (Industrial Product Design), and E (Manufacturing and Engineering Economics) basically involve fundamental principles and knowledge with little engineering analytic activities. Both instructors should already have previous teaching and learning materials to be adapted for this Engineering Design Challenge. Therefore, both instructors should spend up to three days in the preparation of these pedagogic materials.

Specific Steps for Instructor Preparation for Mini Lesson A

The instructors will try these steps first before teaching and coaching students to do the same in this Engineering Design Challenge.

Determining the Wattage (Power) of the individual Cooking Devices:

The instructors will (1) disassemble five to ten food cooking devices so as to understand the inner workings of the products in terms of the functions of each component; (2) collect relevant data (wattage) from the Internet, or the packaging or the products' components.

Designing the Potentiometer:

Using the data in Table 5B, compute the range of resistance needed to design a potentiometer; the calculations will be tabulated (Table 5B). Next, design a potentiometer circuit with the range of resistors found in the last step, using pen-and-paper computations with formulas listed at the end of Table 5B, and simulate the circuit design in ElectronicsWorkbench software.

Building the Potentiometer:

Step 1 - Testing and Measurement: The following steps will be repeated several times with different resistor settings and existing cooking appliances:

1. The instructors will build the designed potentiometer circuit on the breadboard with wires, and resistors with the particular resistance value for the existing cooking appliance;

2. The instructor-built potentiometer will be connected to the existing cooking devices through its electro-thermal interface (*Figure 2B*, P. 42); the container will be filled with water;

3. The food cooking appliance will be connected to the 220-V power outlet; after the power is turned on for the amount of Time for Cooking Task (Table5C), the temperature of the water will be measured and entered in Table 5C;

4. A multi-meter will be used to measure the current flowing into the circuit and the value of the measured current will be entered in Table 5B (in the Current I [A] Exp column). All electrical safety rules must be observed.

5. Calculate the % Error between the calculate value of the current (based on the Wattage rating and V = 220 [V]), and the measured value of the current flowing into the circuit: $\% \text{ Error} = \frac{|I_{Cal} - I_{Exp}|}{I_{Cal}} \times 100\%$. Enter the value in Table 5B.

6. The Range of Current, Wattage, Resistance and other electrical parameters for the potentiometer will be determined and enter in the last row of Table 5B.

If all % Errors are within an acceptable limit of 10%, then this step of potentiometer design will be complete. Otherwise, further experiments might be needed. All experimental information should be recorded.

Step 2 - Finding an Available Potentiometer: Upon completion of the Step 1, the instructors will search the Internet, such as the website of RadioShack at http://www.radioshack.com/home/index.jsp, to find a ready made potentiometer that can perform the required functions with similar Range of Electrical Parameters.

- If an economical potentiometer can be found, then it will be purchased for adaptation with the multi-functional food cooking appliance, and tested with the existing appliances. The instructors should advise students that it is better to use stock items rather than building up from scratch.

- If no economical potentiometer can be found, then it will be designed and built for adaptation with the multi-functional food cooking appliance, and tested with the existing appliances.

Step 3 - Designing the Electro-Thermal Interface: Upon completion of the Step 2, the instructors will design a master electro-thermal interface, which connect the potentiometer and power outlet setup with the food container, can conduct heat but not electrical current. This design will be based on the range of given parameters from Table 5B and 5C (such as the Time for Cooking Task, for a given Temperature in a given Volume of a container, with a given Base Area and Thickness)

Step 4 - Designing and Prototyping a Sample Food Cooking Container Attachment: Upon completion of the Step 3, the instructors will design a sample food cooking container attachment, with is placed on top of the electro-thermal interface. This can perform such function as waffle-making or rice cooking, or any others. Components from existing appliances can be recycled. The instructors should pay attention to the following factors when designing this component:

- Material: Must be safe for users (non-toxic).
    - Function: Appropriate for the specific food cooking task.
    - Safety: No electric hazards.
- Shape: Convenient for filling with food and cleaning.
- Volume: Reasonable for household use.
- Ergonomics: Convenient to hold and risk-free (no sharp corners or edges).
- Aesthetics: Follow the conventions found in existing products.
- Manufacturing: Easy and cheap to manufacturer using existing technology.

Throughout the above four steps, the instructors will provide sample reports on the design process, using the same report writing templates as to be given to students (Appendices A2a, A2b, and A2c).

Table 5B. Electrical Data (V = Constant = 220 V)

Product (Electro- Thermal Converter)	**Wattage P [W] ***	**Current I [A]****			**Resistance R [Ω] *****	**Found/ Calculated by**	**Checked by**
		I_{Cal}	**I_{Exp}**	**% Error**			
Nesco 5 Quart Double Decker Food Steamer - 2 Trays, 60 Minute Timer							
Hamilton Beach 3-in-1 Slow Cooker							
Panasonic 10 Cup Rice Cooker/Steamer							
Deni 3 qt. Slow Cooker/Deep Fryer							
Continental Platinum 4-Slice Stainless Steel & Black Toaster							
Nesco Professional 6 qt. Digital 3-in-1 Pressure Cooker							
Deni 3 Tier Food Steamer							
Kalorik 700 Watt Combi Sandwich/Grill/Waffle Maker							
Chef's Choice WaffleCone Express™ Waffle Cone Maker							
Nostalgia Electrics Old Fashioned Hot Dog Roller Grill/Griddle							
West Bend Breadmaker							
Black & Decker Extra Large Electric Skillet with Glass Lid							
Kenmore Water-Pumping Coffeemaker							
Nesco Snackmaster® Entree™ Food Dehydrator & Jerky Maker							
Krups Egg Express Cooker							
Back to Basics 6 Quart Stir Crazy Corn Popper							
National Presto PowerCrisp" microwave bacon cooker							
Aroma 5-Tier Rotating Food Dehydrator							
George Foreman's G5 Grill with 5 Interchangeable Plates							
Presto Pizzazz Pizza Oven							
Salton Santa Fe Quesadilla Maker							
Aroma 5-Quart Electric Wok							
Aroma Single-Burner Portable Electric Range Hot Plate							
Range of Electrical Parameters:							

Notes:

- P can be found from Internet or packaging.
- ** Calculated (P = IV → V = Constant = 220 V; I = P/V)
- *** Calculated (V = IR → R = V/I where V = Constant = 220 V)

Table 5C. Heat Transfer Data

Product (Food Container)	**Thickness x [in] ***	**Base Area A [in^2]****	**Volume V [in^3]*****	**Tempe-rature T [°C] ********	**Time for Cooking Task T [min] ***********	**Found/ Calculated by**	**Checked by**
Nesco 5 Quart Double Decker Food Steamer - 2 Trays, 60 Minute Timer							
Hamilton Beach 3-in-1 Slow Cooker							
Panasonic 10 Cup Rice Cooker / Steamer							
Deni 3 qt. Slow Cooker/Deep Fryer							
Continental Platinum 4-Slice Stainless Steel & Black Toaster							
Nesco Professional 6 qt. Digital 3-in-1 Pressure Cooker							
Deni 3 Tier Food Steamer							
Kalorik 700 Watt Combi Sandwich/Grill/Waffle Maker							
Chef's Choice WaffleCone Express™ Waffle Cone Maker							
Nostalgia Electrics Old Fashioned Hot Dog Roller Grill/Griddle							
West Bend Breadmaker							
Black & Decker Extra Large Electric Skillet with Glass Lid							
Kenmore Water-Pumping Coffeemaker							
Nesco Snackmaster® Entree™ Food Dehydrator & Jerky Maker							
Krups Egg Express Cooker							

Table 5C. Continued.

Product (Food Container)	Thickness x [in] *	Base Area A [in^2]**	Volume V [in^3]***	Tempe-rature T [°C] ****	Time for Cooking Task T [min] *****	Found/ Calculated by	Checked by
Back to Basics 6 Quart Stir Crazy Corn Popper							
National Presto PowerCrisp" microwave bacon cooker							
Aroma 5-Tier Rotating Food Dehydrator							
George Foreman's G5 Grill with 5 Interchangeable Plates							
Presto Pizzazz Pizza Oven							
Salton Santa Fe Quesadilla Maker							
Aroma 5-Quart Electric Wok							
Aroma Single-Burner Portable Electric Range Hot Plate							

Notes:

- * x is the thickness of the container (also designated as L).
- ** A is the area of the base of the container.
- *** Formulas for the volume varies (if the container's shape makes computation difficult, then water can be pulled into it and then into another container with regular shape such as a calibrated measurement cup, so as to obtain the volume). In most cases, the volume of the container is listed as product information and can be found on the web page or packaging of the product.
- **** T (temperature) can be calculated using formulas such as $\wp = kA\left|\frac{dT}{dx}\right| = kA\left(\frac{T_h - T_c}{L}\right)$ (Serway & Jewett, 2004, p. 624), and others available from Chapter19 and 20 (Serway & Jewett, 2004, pp. 581-640).
- ***** Normally can be found in the user manuals of the food cooking appliances.

Specific Steps for Instructor Preparation for Mini Lesson B through E

Directions for Preparing Instructional Materials:

This covers all Mini Lessons.

- PowerPoint lecture presentation file: Based on the Textbooks to be Used sections in Chapter 1 (pp. 17-20).
- Handouts: Based on the other sources, such as Internet sites (Wikipedia the Free Encyclopedia at http://en.wikipedia.org/wiki/Main_Page, howstuffworks at http://www.howstuffworks.com/, http://electronics.howstuffworks.com/ and others)

Directions for Preparing Learning Materials:

This covers all Mini Lessons.

- Engineering Design Challenge Report Writing Templates: For students to fill in statements, graphics, charts, tables and others according to professional report writing standards (Appendices A2a, A2b, A2c, and A2d).
- Mini Lesson Reflection Paper Writing Templates: For students to fill in statements, graphics, charts, tables and others in a preferred format (Appendices B3a, B3b, C3a, C3b).
- Mini Lesson Quiz Review Guides: For students to review and prepare for quizzes, with sample questions and work-out problems, important principles, formulas, units, constants, and facts data (Appendices A4, B4, C4, D4, and E4).
- Assignment Completion Guide: Explaining the suggested procedures in the Engineering Design Challenge assignments.

Directions for Preparing Physical Samples:

This covers all Mini Lessons.

- Mini Lesson B (Material Selection): Samples of metal (iron/steel, plastics, glass, ceramics) can be found in the school's lab facilities, at home or in crafts supply stores such as Michael's (http://www.michaels.com/art/online/home) and HobbyLobby (http://www.hobbylobby.com/), or building materials suppliers such as HomeDepot (http://www.homedepot.com/), Lowe's (http://www.lowes.com/l), or other sources.
- Mini Lesson C (Design Aesthetics and Graphic Presentation): Pictures of 2D and 3D designed can be found from Internet; 3D art and design samples can be bought from $1.00 stores, or brought from home to show students.

- Mini Lesson D (Industrial Product Design): Visiting local WalMart, K-Mart, Sears and other stores is the best option.

- Mini Lesson E (Manufacturing and Engineering Economics): Sample mold, fixtures and jigs can be used in classroom lecture. They are likely available in the school's manufacturing and construction labs as previous students' works.

Teaching Strategies for an Engineering Design Challenge

This Engineering Design Challenge involves:

- Review of previously learned scientific principles: Electrical circuit analysis, electro-thermal conversion, heat transfer. Instructors should focus on the important principles, formulas and other information relevant to the Engineering Design Challenge.

- Further inquiry in technology: Material selection and manufacturing technology. Instructors should clearly explain the content knowledge topics that have not been previously covered.

- Application of scientific principles: In practical and real-world technological design (multi-functional food cooking device). Instructors should coach students ho to apply theory to practical situations.

- Integration of STEM: Electrical circuit analysis, electro-thermal conversion, heat transfer, material selection, manufacturing technology, and engineering economics. Instructors should foster students' "System Thinking" abilities, i.e., to analyze design problems from different perspectives and to integrate all analysis into a coherent and logical solution, with adherence to established criteria and tradeoffs on minor issues.

- Moving beyond STEM: Extension of the main Engineering Design Challenge beyond the purely scientific and technical, into design aesthetics, ergonomics, and humanities (design ethics, environmental protection, consumer rights, etc.). Instructors should foster students' ability in critical thinking on the impact of design on human happiness, and sustainable economic growth environmental protection.

The open-ended and interdisciplinary nature of this project requires the instructors to (1) provide opportunities for students to explore and experiment, make discoveries, and make mistakes; (2) to cover additional knowledge content specific to the project, or to help students find pertinent information on their own efforts; and (3) to tutor and coach groups of students in a student-centered pedagogic approach. The following guidelines draw reference from the *Sample EDC.pdf* (p. 17), extracted March 1, 2009, from the NCETE Core 4 Website at http://bb.usu.edu, and are intended to help instructors make this activity as fruitful as possible. Instructor should

Discussions with students:

- Be sure to discuss the designs before and after each steps of the Engineering Design Challenge, in all Mini Lessons; and make careful observations of student design activities. Remind students of what they have already done; compare their designs to previous ones they have tried in earlier runs. This will help them evaluate their progress. Discussing should be focused on what worked and what don't, the reasons, and how students can improve their design the next time.

Lecture Management: Refer to *Sample EDC.pdf* (NCETE, 2009, p. 17).

- Watch carefully what students do and listen carefully to what they say during the lecture. This will help instructors understand student thinking and guide them to better understanding the topics.

Coaching:

- "Steer students toward a more scientific approach. If they have changed multiple aspects of a design and observed changes in results, ask them which of the things they changed caused the difference in performance. If they are not sure what caused the change, suggest they try changing only one thing at a time. This helps them learn the value of controlling variables" (Sample *EDC.pdf* (NCETE, 2009, p. 17)

Grooming:

- "Model brainstorming, careful observation, and detailed description using appropriate vocabulary."
- "Ask "guiding" or "focusing" questions."
- "Require students to use specific language and be precise about what they are describing."
- Encourage conjecturing. Get students to articulate what they are doing in the form of "I want to see what will happen if…"

Fostering Cooperation:

- "Compare designs to those of other groups. Endorse borrowing. After all, engineers borrow a good idea whenever they can. However, be sure that the team that came up with the good idea is given credit in documentation."
- "Emphasize improvement over competition. The goal of the challenge is for each team to improve its own design. However, there should be some recognition of designs that perform extremely well. There should also be

recognition for teams whose designs improve the most, for teams that originate design innovations that are used by others, for elegance of design, and for quality of construction."

Foster understanding:

- "Connect what students are doing to what engineers do. It will help students see the significance of the design challenge if they see that the process they are following is the same process that adult engineers follow."
- "Help students understand that designs that 'fail' are part of the normal design process. Much can be learned from a "failed" design. Discuss how engineers and scientists learn from their failures."

Helping Students Understand the Design Process

Instructors should help students to:

- Understand the nature of the engineering design process: (1) It is both linear (step-by-step) and recursive or cyclic (moving back to make changes to the previous step or starting all over again, in an iterative process of design-test-redesign, until a satisfactory solution is reached); and (2) it is systematic (involving many branches of STEM and many factors beyond STEM). A Learning Log (Appendix LL) will help students record these steps.
- Explain the design process used in this Engineering Design Challenge: Once students have sufficient experience in designing, building, and testing models, at the end of each Mini Lesson, they will describe the design process they are undertaking in the required reflection papers, reports and other assignments, which will be used as a reinforcement to what they learn in private study as well as in collaborative group activities. Through collaborative activities, students will understand that they can learn from the successes and failures of others too.

Chapter 6: Classroom Sessions

This Chapter will explain in details how all Sessions in each Mini Lesson will be delivered, according to the Class Schedule for the Whole Course (pp. 21-23). These sessions are intended to be a guide for the instructors to use when managing this Engineering Design Challenge project. Instructors will know the conditions of the class and how to best pace the sessions so as to make optimum use of the material included in this guide. Classroom-specific adjustments can be made to this guide

Mini Lesson A (Circuit Analysis and Heat Transfer)

Session 1: Introduce the Challenge

This session can be completed in one class period.

Overview:

This session introduces students to the Engineering Design Challenge (syllabus, home works, design activities, timelines, grading policies, etc.); and briefly explain the engineering design process (both “Analytic Reduction” and “System Thinking” models, etc.). This is a busy session.

Goals:

Students will:

1. Understand the objectives and characteristics of the Engineering Design Challenge.

2. Understand the difference between analytic reduction and system thinking, between linear and recursive design sequence, between predictive and trial-and-error approaches, and others issues related to engineering design process.

3. Understand the importance of collaboration among design team (Student Groups) members, and the relationship between individual efforts and team works.

Materials:

1. Computer with projector and screen;

2. PowerPoint presentation and handouts;

3. Display of previous design sample and existing product samples.

Detailed Steps:

1. Issue of the Course Materials CD to students and Introduction to Engineering Design Challenge.

   PowerPoint lecture (15 minutes) will be followed by a Question-and-Answer period (15 minutes).

2. NCETE High School Engineering Design Process.

   PowerPoint lecture (20 minutes) will be followed by a Question-and-Answer period (20 minutes).

A Note about the lecture:

The instructor will use the samples of existing products as examples to help explaining the engineering design process.

Session 2: Market Research

This session can be completed in one class period.

Overview:

The instructor will briefly show students the basics of market research process, and guide students to conduct an Internet market research activity.

Goals:

Students will:

- Understand the importance and function of market research before engineering design process starts;
- Understand the four common types of market research: (1) Internet research; (2) purchasing samples online or through store visitation; and (3) survey with store managers, technical experts, customers, etc.
- Conduct an Internet research on electrical data related to some typical food cooking appliance, from WalMart and Sears-K-Mart websites, and fill out Wattage and Volume data Tables 5B and 5C (pp. 69-70).

Materials:

- Computer with projector and screen;
- PowerPoint presentation and handouts;
- Display and explanation of previous design sample and existing product samples.
- Tables 5B and 5C in the Report on Existing Products writing template (to be filled by students).

Detailed Steps:

1. Market Research.

   PowerPoint lecture (15 minutes) will be followed by a Question-and-Answer period (15 minutes).

2. Student Internet market research activity.

   Under observation of the instructor, students will collect relevant electrical data for typical food cooking appliances from an instructor-provided list (*Figure 2A*, pp. 40-43, or Table 5A, pp. 64-65). The list is to be updated.

A Note about the market research activity:

Instructor will coach students in completing the activity.

Session 3: Ohm's Law and Circuit Analysis

This session can be completed in one class period.

Overview:

The instructor will review the subject of circuit analysis, explain the related principles, concepts, formulas, units, and their applications; and help students to calculate the currents and resistance of the sample products investigated in Session 1.

Goals:

Students will:

- Further their understanding of the important principles of circuit analysis.
- Apply circuit analysis principles and formulas to solve for related current and resistance and enter the data in the Tables 5B and 5C.

Materials:

- Computer with projector and screen;
- PowerPoint presentation and handouts;
- Display of previous design sample and existing product samples.

Detailed Steps:

1. Review of Ohm's Law and Circuit Analysis with sample worked out problems.

   PowerPoint lecture (15 minutes) will be followed by a Question-and-Answer period (15 minutes).

2. Student computations and tabulations of currents and resistances, on different existing food cooking appliances.

   The instructor will provide in-class coaching and tutoring.

A Note about the lecture:

The instructor will use the samples of electrical circuits in the existing products as examples to help explaining Ohm's Law and circuit analysis.

Session 4: Reverse Engineering

This session can be completed in one class period.

Overview:

The instructor will guide students in conducting a reverse engineering activity, by disassembling several existing food cooking appliances, analyze and record the shapes, dimensions, colors, mass, materials, and functions of each components; and re-assembling the products. All electrical safety rules will be explained before the reverse engineering process start.

Goals:

Students will, under the guidance of the instructor:

1. Understand the functions of each component of the food cooking appliances;

2. Understand the scientific principles behind these functions;

3. Understand how these scientific principles and functions can be incorporated in the Engineering Design Challenge.

Materials:

- Computer with projector and screen;
- PowerPoint presentation and Principles & Formulas/Unit Conversion Sheet (Appendix A5a);
- Display of existing product samples.

Detailed Steps:

1. Introduction to reverse engineering process.

   PowerPoint lecture (15 minutes) will be followed by a Question-and-Answer period (15 minutes).

2. Student reverse engineering activity (in class) and report writing, on different existing food cooking appliances.

   The instructor will provide in-class coaching and tutoring.

A Note about the activity:

The instructor will clearly explain all electrical safety rules and have student sign an Understanding of Safety Rule Statement (Appendix A5b).

Session 5: Potentiometer Design (Computation)

This session can be completed in one class period.

Overview:

The instructor will guide students in computing the ranges of relevant electrical parameters for the design and fabrication of a potentiometer with multiple resistance and current settings, and in the design of electrical circuitry for the potentiometer (circuitry diagram). All related issues will be explained.

Goals:

Students will, under the guidance of the instructor, use pen-and-pencil approach to:

- Compute the relevant electrical parameters;
- Design the electrical circuitry for the potentiometer.

Materials:

- Computer with projector and screen;
- PowerPoint presentation Circuit Analysis and Heat Transfer (Appendix A1a) and relevant handouts (Appendix A1ba);
- Display of existing product samples.

Detailed Steps:

1. Introduction to potentiometer circuitry design and the application of potentiometers.

   PowerPoint lecture (15 minutes) will be followed by a Question-and-Answer period (15 minutes).

2. Student pen-and-pencil computations and design (in class) and report writing (after class), for a new multi-functional food cooking appliance.

   The instructor will provide in-class coaching and tutoring.

A Note about the lecture:

The instructor will clearly explain how potentiometers are used in real-world design practices.

Session 6: Potentiometer Design (Simulation with ElectronicsWorkbench)

This session can be completed in one class period.

Overview:

The instructor will tutor students in using ElectronicsWorkbench for the design of the potentiometer circuitry (circuitry diagram), and for the simulation of the digital circuitry in obtaining needed data.

Goals:

Students will, under the guidance of the instructor,

- Learn the relevant tools of ElectronicsWorkbench software;

- Design and simulating the electrical circuitry for the potentiometer with ElectronicsWorkbench, to obtain needed data.

Materials:

- Computer with projector and screen;
- PowerPoint presentation;
- ElectronicsWorkbench software;
- Relevant handouts on ElectronicsWorkbench tools (Appendix A1c).

Detailed Steps:

1. Introduction to the basic design and simulation tools of ElectronicsWorkbench software.

   Software demonstration (20 minutes) will be followed by a Question-and-Answer period (20 minutes).

2. Student exercise with ElectronicsWorkbench software (in class) and report writing (after class), for a new multi-functional food cooking appliance.

   The instructor will provide in-class coaching and tutoring.

A Note about the lecture:

The instructor will give a step-by-step demonstration of the relevant Graphic User Interface, settings, and tools of the ElectronicsWorkbench software, and show students how to find additional information.

Session 7: Potentiometer Design (Breadboard Testing) and

Session 8: Potentiometer Design (Report Writing)

These two sessions can be completed in two class period. If additional time is needed, after-school time as well as part of the next Session can be used to complete the assignment.

Overview:

The instructor will tutor students in (1) safely using breadboard, resistors, wires, multi-meter and other electronics components and devices to design, fabricate and test a mock-up potentiometer; (2) in locating an economical potentiometer with similar range of electrical parameters, from major electronics supplier such as RadioShack (under a maximum retail price of $10.00); and (3) in case such potentiometer cannot be found, design one for mass production, drawing reference from the potentiometer circuitry found the Session 4: Reverse Engineering.

Goals:

Students will, under the guidance of the instructor,

- Learn to fabricate a mock-up potentiometer with breadboard, resistors, wires and other electronic components, using the circuitry design made in Sessions 5 (pen-and-pencil computation and circuitry diagram) and 6 (circuitry diagram in ElectronicsWorkbench), connecting the wires to one of the resistors at a time; and then connect the whole mock-up potentiometer to the electro-thermal interface of the relevant food cooking appliance one at a time;

- Learn to test the electrical circuitry for the mock-up potentiometer with testing devices such as a multi-meter, measuring the relevant data (such as current and resistance) with one potentiometer connection at a time.

Materials:

- Computer with projector and screen;

- PowerPoint presentation;

- Demonstration with a potentiometer circuitry on breadboard;

- Handouts on on Potentiometer Fabrication and Testing (Appendix A1d).

Detailed Steps:

1. Introduction to the breadboard circuitry layout, to the correct use of electrical measuring devices, and to relevant electrical safety rules.

   Breadboard circuitry demonstration (15 minutes) will be followed by a Question-and-Answer period (15 minutes).

2. Student exercise with breadboard circuitry layout, connection to relevant food cooking device’s electro-thermal interface, and measuring (in class) and report writing (after class), for a new multi-functional food cooking appliance.

3. Student Internet search for a ready-made potentiometer with similar range of electrical parameters.

4. Student design of a potentiometer for mass production, for the multi-functional food cooking device under this Engineering Design Challenge (in case the needed potentiometer cannot be found in the market place), drawing reference from the potentiometer circuitry found the Session 4: Reverse Engineering.

   The instructor will provide in-class coaching and tutoring.

A Note about the lecture:

The instructor will clearly explain all relevant electrical safety rules and watch students carefully while they are engaged in the exercise.

Session 9: Heat Transfer (Lecture/Video/Display), and

Sessions 10 & 11: Heat Transfer (Computations)

These two sessions can be completed in two class period. If additional time is needed, after-school time as well as part of the next Session can be used to complete the assignment.

Overview:

The instructor will review with students some particular principles of physics covered in Chapters 19 and 20 of the Serway and Jewett textbook (*Physics for Scientists and Engineers, 6th Ed., Volume 1*, 2004); or Chapters/Sections 1.4, 3.4, 4.4, 5.4 in Crawford et all textbook (*Physics in Context*, 2005), such as:

1. The principles of heat transfer;

2. Temperature scale and measurement;

3. Zeroth Law of Thermodynamics;

4. Physical properties that change with temperature (the volume of a liquid; dimension of a solid; pressure of a gas at constant volume; volume of a gas at constant pressure; electric resistance of a conductor;

5. Energy in thermal systems (internal energy, heat engines, the First Law of Thermal Dynamics and its applications, the Second Law of Thermodynamics, and energy dissipation);

6. Specific heat and conservation of energy (Calorimetry);

7. Energy transfer mechanisms and rate in thermal systems (heat flow rate, heat conduction, convection and radiation);

8. Resistance in thermal systems.

The instructor will then coach students on how to systematically apply some of the above principles in the design of the Multi-Functional Food Cooker in this Engineering Design Challenge.

Goals:

Students will, under the guidance of the instructor,

- Understand the principles of conservation of energy, the 0^{th}, 1^{st}, and 2^{nd} Laws of Thermodynamics;

- Understand how electrical energy changes to thermal energy, and how heat energy is transferred from one medium to another, and the rate of such transfer;

- Learn how to apply principles of thermodynamics and heat transfer to real world engineering design.

Materials:

- Computer with projector and screen;

- PowerPoint presentation;

- Showing Internet videos;

- Display of a sample food cooking appliance;

- Handouts on Heat Transfer Computations (Appendix A1e).

Detailed Steps:

1. Review of principles of thermodynamics and heat transfer, using PowerPoint presentation to explain the concepts and formulas, and a sample food cooking appliance as an example to show how these concepts work in a real world situation.

   Breadboard circuitry demonstration (30 minutes per session, for two sessions) will be followed by a Question-and-Answer period (15 minutes).

2. Student will do 2 word problem exercises in-class (under the instructor's coaching), and two similar problems independently at home. This will

help students to review principles of physics relevant to the Engineering Design Challenge.

3. Under the guidance of the instructor, students will apply principles of thermodynamics and heat transfer to the design of the Electro-Thermal Interface and Food Container Attachment, making calculations on relevant parameters such as temperature change rate, time it takes for a specific temperature change with given volume of water in a stainless steel container with a given bottom surfaces area and thickness;, and others. Calculations will be tabulated in the Group and Company Report on Heat Transfer Computations.

   The instructor will provide in-class coaching and tutoring.

A Note about the lecture:

The materials are mostly covered in previous physics courses; thus, the instructor will focus on the relevant principles of thermodynamics and heat transfer, and their application in the Engineering Design Challenge, and spend more time coaching students in solving the design problem.

Sessions 13 - 16: Improving Design of Potentiometer (Fabrication and Testing)

These four sessions can be completed in four class period. If additional time is needed, after-school time as well as part of the next Session can be used to complete the assignment.

Overview:

Based on the particular principles of physics (thermodynamics and heat transfer) and overall application of these principles in the Engineering Design Challenge, as well as relevant computations made during the Sessions 9 - 12, the instructor will coach the Student Groups (3 - 5 students to be randomly selected) on:

1. Making necessary changes to the potentiometer design completed in Sessions 5 - 8, in light of the newly reviewed principles of thermodynamics and heat transfer; and recorded the results as design changes in Engineering Notebook and in the Group and Company Report on Potentiometer Design and Testing;

2. Completing the potentiometer design;

3. Understanding the concept of re-design and the meaning of the design process as recursive and cyclic.

Goals:

Students will, under the guidance of the instructor,

- Make necessary changes to the design of potentiometer completed previously, in light of the newly reviewed principles of thermodynamics and heat transfer;
- Completing the potentiometer design, and record the final design solution in the Group and Company Report on Potentiometer Design and Testing;
- Understand the recursive and cyclic nature of engineering design process.

Materials:

- Computer with projector and screen;
- PowerPoint presentation;
- Handouts on Potentiometer Fabrication and Testing (Appendix A1d).

Detailed Steps:

1. Coaching students on the application of the principles of thermodynamics and heat transfer, using PowerPoint presentation.

   PowerPoint presentation and review/critique (10 minutes per session, for two sessions) will be followed by a Question-and-Answer period (10 minutes).

2. Under the guidance of the instructor, students will conduct re-design activities and record the results in the Group and Company Report on Potentiometer Design and Testing.

   The instructor will provide in-class coaching and tutoring.

A Note about the lecture:

The relevant engineering predictive analysis knowledge content will have been reviewed in previous Sessions 9 - 12. Thus, the instructor will focus on coaching students on their applications in this Engineering Design Challenge.

Sessions 17 - 23: Design of Electro-Thermal Interface and Food Containers (Supervised Student Activity)

These seven sessions can be completed in seven class period. If additional time is needed, after-school time as well as part of the next Session can be used to complete the assignment.

Overview:

Based on the particular principles of physics (thermodynamics and heat transfer) and overall application of these principles in the Engineering Design Challenge, as well as relevant computations made during the Sessions 9 - 12, the instructor will coach the same Student Groups on:

1. Designing the Electro-Thermal Interface and at least three Food Container Attachments for the Multi-functional Food Cooker, and record the engineering design process and results in the Engineering Notebook and in the Group and Company Report on Design of New Food Cooking Electro-Thermal Interface and Food Containers.

2. Understanding the concept of tradeoffs in the design process.

Goals:

Students will, under the guidance of the instructor,

- Conduct in-class "brainstorming" sessions to come up with workable design ideas within their separate groups, and to share them with other groups; record all design ideas in the Engineering Notebooks and in the Group Report on Design of New Food Cooking Electro-Thermal Interface and Food Containers.

- Under the guidance of the instructor, and management from the elected Company Manager, analyze, compare and synthesize design ideas from different Student Groups into a set of design ideas for the whole class, and to record the process and results in the Company Report on Design of New Food Cooking Electro-Thermal Interface and Food Containers. At this stage, the design ideas can be represented by sketches and notes made in Engineering Notebook, and scanned images of these sketches to be included in the Company Report on Design of New Food Cooking Electro-Thermal Interface and Food Containers.

Materials:

- Computer with projector and screen;

- Samples of existing food cooking appliance;

- Handouts on Electro-thermal Interface and Food Containers Design (Appendix A1f).

Detailed Steps:

1. Coaching students on the application of the principles of thermodynamics and heat transfer, using samples of existing food cooking appliance.

   Review/critique at the end of each Session (10 minutes per session, for Sessions 19, 21, 23) will be followed by a Question-and-Answer period (5 minutes).

2. Under the guidance of the instructor, students will conduct relevant group design activities and record the results in the Group and Company Report on Design of New Food Cooking Electro-Thermal Interface and Food Containers.

   The instructor will provide in-class coaching and tutoring.

A Note about the lecture:

The instructor will spend most of classroom meeting time on coaching students in their respective Design Groups.

Session 24: Quiz A (Electricity and Heat Transfer)

This session is for the Mini Lesson A Quiz, a general review of the previous works, and a brief introduction to the Mini Lesson B (Material Selection).

Overview:

The Quiz A will include 8 Multiple-choice and 2 True and False questions, and will test the students on:

1. Basic principles of electrical circuit analysis and its application in real world engineering design (4 Multiple-choice);

2. Basic electrical safety rules (2 True and False);

3. Basic principles of thermodynamics and heat transfer (4 Multiple-choice).

Goals:

Students will,

- Take Quiz A (15 minutes at the start of the Session).

- Raise additional questions during the after-test review.

Materials:

- Quiz A form;
- White board and markers.

Detailed Steps:

1. Quiz A (15 minutes);
2. Review/critique for student works during Mini Lesson A (20 minutes);
3. Question-and Answer Session (10 minutes);
4. Brief introduction to Mini Lesson B (Material Selection, 10 minutes).

A Note about the lecture:

Give student praise for their patience, efforts, and accomplishment so far. Encouraging students to improve learning process (be specific and courteous in explaining the shortcomings observed and new expectations for changes).

Chapter 7:

Evaluation/Assessment)

This Chapter shall explain how student learning will be evaluated. Evaluation and assessment of expected student learning results, as explained in Chapter 1 (pp. 31-32, and 37-39), will be generally based on the quality of

- Assignment: Group and Company Reports (summaries of design activities), Engineering Notebook, Mock-ups, CAD drawings and prototype making (related to design activities), Concept Maps and Reflection Paper (on Mini Lessons topics), and exercises.

- Presentation: Design Presentation, and PowerPoint Presentation (on Mini Lessons topics).

- Testing: End of Mini Lesson Quizzes.

General Guidelines

(Reference: Week 13 PowerPoint presentation, NCETE Core 4, Slides 18-19)

1. **For Assessment of Progress:**

- Monitor and facilitate the process: Observe student design process and provide critical advice when needed.

- Mentor the process: Provide hint, advice and assistance to students when requested. Use prompts to manage flow of events.

- Utilize rubrics: As a general framework for judging student performance as objectively and rationally as possible. Not as a rigid quantitative calculation of scores.

- Make the assessments authentic: Based on connection with real-world conditions.

- Be willing to spend more time and effort for authentic assessments: Observe Instructors' Office Hours, and grant additional appointments to meet with students if possible.

- Vary the Instrument of Evaluation and Assessment used: Rubrics for Writing Assignment and Evaluation Criteria for Engineering Design Challenge use different Instruments of Evaluation.

2. **For Evaluation:**

- Take time to reflect, individually and as a group: At each step of students' design process, give a short evaluation and encourage students to rethink about already accepted design ideas and to break away from the "box" ("recursive process").

- Share feelings and experiences: Be generous to share past experience and personally acquired knowledge (especially those not mentioned in textbook).

- Discuss what worked well: With students during each step of the Engineering Design Challenge, during and after lectures.

- Discuss what needs change: With students during each step of the Engineering Design Challenge, during and after lectures.

- Share ideas that will lead to new inquiries, thus new projects.

Items for Evaluation and Assessment

1. **Student Understanding and Application of STEM Content:**

    - Understanding of STEM knowledge content: Computations reported in Group and Company Reports, and Engineering Notebook (related to design activities), and end of Mini Lesson Quizzes;

    - Application of STEM knowledge content: Design-related statements in the Group and Company Reports (related to design activities);

2. **Student Ability in Applying Engineering Design Process:**

    - Understanding of engineering and product design process:

        - The "Analytic Reduction: Computations reported in Group and Company Reports, and Engineering Notebook (related to design activities);

        - The "System Thinking" Model: Engineering Notebook, Mock-ups, CAD drawings and prototype making;

    - Skills in engineering and product design:

        - Brainstorming: Both quantity and quality of design ideas generated in brainstorming sessions;

        - Engineering Notebook: Ability to follow the conventions;

- <u>Sketch:</u> Graphics, notes and dimensions must be easy to understand;
- <u>Report:</u> Logical reasoning and correct English grammar and spelling;
- <u>CAD:</u> Correct usage of drafting conventions;
- <u>Simulation:</u> Project-related basic skills in ElectronicsWorkbench (for circuit analysis and design), and Granta Materials Intelligence (for Material selection);
- <u>Internet search:</u> For (1) locating relevant STEM information; (2) conducting market research; and (3) locating suppliers.
- <u>Mock-ups:</u> Must show correct volume and spatial relations among the components;
- <u>Prototyping:</u> Must be fully functional;
- <u>PowerPoint Presentation:</u> Must follow basic guidelines (Appendix PP).

Instrument of Evaluation and Assessment

Scoring Notations

Rubric	Excellent	Very Good	Good	Fair	Basic	Not Observed
Rating Scale	5	4	3	2	1	0

1. **<u>Rubrics for Writing and PowerPoint Presentation Assignment</u>:** The following rubric will be used for evaluating the quality of student writing assignment:

   <u>For Reflection Papers:</u>

   - **<u>Directions:</u>** Students will select one of the Teacher- or Learner-generated Essential Questions (or ask a new Learner-generated Essential Question to start with), write a paper to record thoughts, beliefs, and understandings as they evolve and change over time, with self-designed tables, graphs, concept maps and other visual elements. The paper should be doubled-spaced, with a limit of 10 pages maximum and should include: (1) explanation of the most important principles and/or knowledge of materials science learned in the Mini Lesson, in comparison to previous assumption; (2) the way these principles are reflected in the existing engineering design; (3) the way these principles and/or knowledge will be applied in this Engineering Design Challenge, and in the future design activities; (4) any personal thoughts, comments and suggestions on the organization of the course materials and on the delivery of knowledge content by the instructor; and (5) bibliographic references according to APA format.

- **Standard:** The paper should answer the selected Essential Question, based on an integration of (1) STEM principles and content knowledge covered in previous courses and in the respective Mini Lesson; (2) student's own additional library or Internet search; and (3) real-world examples supporting the STEM principles and content knowledge

- **Scoring Rubric:**

    - Not Observed: Student fails to understand the selected Essential Question, and to provide it with an answer based on relevant information.

    - Basic (1.0): Student does understand the selected Essential Question, and provide it with an answer based on relevant information; however, the paragraphs are not well-constructed, or the sentences are not well organized in a logical way. The Essential Question is addressed; the information is clearly related to the main topic; but no details and/or examples are given. All sources (information and graphics) are accurately documented, but many are not in the recommended or required format. A few grammatical, spelling, and punctuation errors.

    - Fair (2.0): Student does understand the selected Essential Question, and provide it with an acceptable answer based on relevant information; however, the paragraphs are not well-constructed, or the sentences are not well organized in a logical way. The Essential Question is addressed; the information is clearly related to the main topic; but no details and/or examples are given. All sources (information and graphics) are accurately documented, but many were not in the recommended or required format. A few grammatical, spelling, and punctuation errors.

    - Fair (2.0): Student does understand the selected Essential Question, and provide it with an adequate answer based on relevant information; however, the paragraphs are not well-constructed, or the sentences are not well organized in a logical way. The Essential Question is addressed; the information is clearly related to the main topic; but no details and/or examples are given. All sources (information and graphics) are accurately documented, but many are not in the recommended or required format. A few grammatical, spelling, and punctuation errors.

- Good (3.0): Student does understand the selected Essential Question, and provide it with a better-than-adequate answer based on relevant information; the paragraphs are well-constructed, the sentences are well organized in a logical way. The Essential Question is addressed; the information is clearly related to the Essential Question; most paragraphs include introductory sentence, explanations or details, and concluding sentence. The information is clearly related to the Essential Question selected; it provided one to two supporting details and/or examples. All sources (information and graphics) are accurately documented, but a few were not in the recommended or desired format. There were almost no grammatical, spelling and punctuation errors.

- Very Good (4.0): Student does understand the selected Essential Question, and provide it with a very adequate answer based on relevant information; the information is very organized with well-constructed paragraphs and subheadings; all paragraphs include an introductory sentence, explanations or details, and concluding sentence. The Essential Question is answered with logically organized sentences. The information clearly relates to the Essential Question; it includes several supporting details and/or examples. All sources (information and graphics) are accurately documented in the recommended or required format. There are no grammatical, spelling and punctuation errors.

- Excellent (5.0): Student does understand the selected Essential Question, and provide it with a very adequate answer based on relevant information; the information is very organized with well-constructed paragraphs and subheadings; all paragraphs include an introductory sentence, explanations or details, and concluding sentence. The Essential Question is answered with logically organized sentences. The information clearly relates to the Essential Question; it includes several supporting details and/or examples. All sources (information and graphics) are accurately documented in the recommended or required format. There are no grammatical, spelling and punctuation errors. The paper is well written with interesting information not well explained in the Mini Lesson.

For Reports related to Engineering Design Challenge

- **Directions:** Detailed directions are available from Chapter 1 (for Mini Lesson A; pp 37), and in relevant writing templates (Appendices A2a, A2b, A2c, A2d, B2).

- **Standard:** There are slight differences in the standards for the individual reports. However, all report should include (1) tabulated data including measurements and calculations well checked; (2) graphs or pictures to illustrate design, testing and/or production processes; (3) descriptive, explanatory and conclusive statements of design, testing and/or production processes; and (4) reference (if necessary). The reports should be (1) written using the instructor-provided templates (Appendices A2a, A2b, A2c, A2d, B2); and (2) reviewed and edited by peer members in the student groups, to remove any possible wrong statement or computational errors, as well as grammatical, spelling and punctuation errors, before submissions to the instructors.

- **Scoring Rubric:**

  - Not Observed: Students do understand and complete the assign design, testing and production tasks, as illustrated by adequate documentation of data; however, they fail to provide acceptable descriptive and explanatory statements of design, testing and/or production processes. The report includes only a limited but not adequate conclusion or summary on the design, testing and/or production processes. Bibliographic entries are not provided nor written according to APA style. Information is not correctly assigned to relevant headings in the template to facilitate reading, and graphical details are missing. Many grammatical, spelling, and punctuation errors, as well as poorly-organized sentences and paragraphs.

  - Basic (1.0): Students do understand and complete the assign design, testing and production tasks, as illustrated by adequate documentation of data; in addition, they do provide barely acceptable descriptive and explanatory statements of design, testing and/or production processes. The report includes only a limited and barely acceptable conclusion or summary on the design, testing and/or production processes. Bibliographic entries are not provided nor written according to APA style. Information is correctly assigned to relevant headings in the template to facilitate reading, but graphical details are missing. Many grammatical, spelling, and punctuation errors, as well as poorly-organized sentences and paragraphs.

  - Fair (2.0): Students do understand and complete the assign design, testing and production tasks, as illustrated by adequate documentation of data; in addition, they do provide adequate descriptive and explanatory statements of design, testing and/or production processes. The report includes an acceptable conclusion or summary on the design, testing and/or production processes. Bibliographic entries are provided and written according to APA style. Information is correctly assigned to relevant headings in the template to facilitate reading, and some graphical details are included. A few grammatical, spelling, and punctuation errors, as well as poorly-organized sentences and paragraphs.

- Good (3.0): Students do understand and complete the assign design, testing and production tasks, as illustrated by adequate documentation of data; in addition, they do provide more than adequate descriptive and explanatory statements of design, testing and/or production processes. The report includes an adequate conclusion or summary on the design, testing and/or production processes. Bibliographic entries are provided and written according to APA style. Information is correctly assigned to relevant headings in the template to facilitate reading, and adequate amount of graphical details are included. Very few grammatical, spelling, and punctuation errors, or poorly-organized sentences and paragraphs.

- Very Good (4.0): Students do understand and complete the assign design, testing and production tasks, as illustrated by adequate documentation of data; in addition, they do provide descriptive and explanatory statements of design, testing and/or production processes, with well-written and logically organized sentences and paragraphs. The report includes an adequate conclusion or summary on the design, testing and/or production processes. Bibliographic entries are provided and written according to APA style. Information is correctly assigned to relevant headings in the template to facilitate reading, and adequate amount of graphical details are included. Very few grammatical, spelling, and punctuation errors.

- Excellent (5.0): Students do understand and complete the assign design, testing and production tasks, as illustrated by adequate documentation of data; in addition, they do provide descriptive and explanatory statements of design, testing and/or production processes, with well-written and logically organized sentences and paragraphs. The report includes an adequate conclusion or summary on the design, testing and/or production processes. Bibliographic entries are provided and written according to APA style. Information is correctly assigned to relevant headings in the template to facilitate reading, and adequate amount of graphical details are included. There are no grammatical, spelling and punctuation errors. The report is well written with professional quality.

For PowerPoint Presentations (including Concept Maps and Final Design Presentation)

- **Directions:** Use PowerPoint software to create a 10-slided presentation based on the written Laboratory Report, as a tool for presenting the findings and the design ideas to the class.

- **Standard:** There are slight differences in the standards for the PowerPoint and Concept Maps Presentations, and for the Final Design Presentation. However, all presentations should include a professional-looking PowerPoint Presentation, which (1) fall within the limitation of 15 slides maximum and can be presented within a 20 minutes time slot; (2) include text and graphs or pictures, as well as video clips or Internet links (if necessary), that are well arranged to illustrate a. STEM principles, concepts and applications, or b. design ideas, processes and results; (3) helps to efficiently deliver knowledge content or explain relevant topics by a. clearly and succinctly explaining them step-by-step, in a logical and coherent sequence; and b. using correct English vocabulary and grammars; (4) allow time for the audience to ask questions; (5) involves the audience in an active manner; (6) include references; and (7) include special effects (if needed) (see Appendices PP for requirement). Preferably, the PowerPoint presentation file should be reviewed and edited by peer members in the student groups, to remove any possible wrong statement or computational errors, as well as grammatical, spelling and punctuation errors, before submissions to the instructors and presentation to the class. After the presentation members of the class will fill out Evaluation Form to give feedbacks, comments and suggestions (Appendix PP-EF); and the instructors will give a statistical summary and email it to the presenter.

- **Scoring Rubric:**

  - Not Observed: The presentation is poorly or NOT related to the assigned Mini Lesson topics or Engineering Design Challenge process, and reflects very little or NO research and preparation effort. The PowerPoint presentation file is not developed at all by presenters to guide their part of the presentation. The presentation is too short, moves into content without an introduction, presents too many not so relevant or even irrelevant topics, and only a few marginally related topics but with limited details and only a few examples; is poorly organized, and lacks coherence. NO modern educational technology is used to enhance learning. The PowerPoint presentation file is NOT very well written and contained many errors. NO references are included to aide further study. Ratings of class members on the Evaluation Form are mostly Not Observed with only a few Fair ratings.

  - Basic (1.0): The presentation is only marginally related to the assigned Mini Lesson topics or Engineering Design Challenge process, and reflects little research and preparation effort. The PowerPoint presentation file is not acceptably developed by presenters to guide their part of the presentation. The presentation is brief, moves into content without an introduction, presents only major content topics with limited details, contains only a few examples, is poorly organized, and lacks coherence. NO modern educational technology is used to enhance learning. The PowerPoint presentation file is NOT well written and contained many errors. NO references are included to aide further study. Ratings of class members on the Evaluation Form are mostly Not Observed to Fair with only a few Good ratings.

- Fair (2.0): The presentation is somewhat related to the assigned Mini Lesson topics or Engineering Design Challenge process, but fails to include some expected content and the handout(s). There is insufficient evidence that much effort was expended to researching and preparing for the presentation. The PowerPoint presentation file is barely developed by presenters to guide their part of the presentation, and fails to include enough content with sufficient details to support the selected topic. The presenter fails to adequately introduce their topic and presents the content in a mechanical manner with little enthusiasm displayed. Only traditional presentation technologies were used to facilitate learning. NO modern educational technology is used to enhance learning. The PowerPoint presentation file is NOT very well written and contained many errors. NO references are included to aide further study. The handout(s) is/are very limited in content, contained some serious writing flaws, and included only a few references for further study. Ratings of class members on the Evaluation Form are mostly Fair to Good with only a few Very Good and Excellent ratings.

- Good (3.0): The presentation is somewhat related to the assigned Mini Lesson topics or Engineering Design Challenge process; and include enough expected content and the handout(s). The presentation reflected some research and preparation effort but only a few references are presented in class and/or included in the handout(s) and lesson plans. The PowerPoint presentation file is acceptably developed by presenters to guide their part of the presentation; and contains mostly broad content topics with limited details to support the selected topic. The PowerPoint presentation is only partially used to guide each group member's presentation. A mostly traditional introduction is used to launch the presentation and audience involvement is very limited, mostly to responding to presenter questions. Mostly traditional educational technology is used to facilitate learning. The presentation seems to be a little disorganized at times but comes together at the end. The handout(s) contain(s) the main points with some details and is/are satisfactorily written with only minor flaws. Most of the criteria on the group presentation form were rated by class members as Good to Very Good with a few Excellent ratings.

- Very Good (4.0): The presentation is appropriately related to the assigned Mini Lesson topics or Engineering Design Challenge process; and reflects an adequate research and preparation effort as evidenced through the content presented and in the handout(s). The PowerPoint presentation file is adequately developed by presenters to guide their part of the presentation; and contains relevant content topics with enough details to support the selected topic. The selected content is introduced and techniques are used to sustain class attention and get then actively involved. The topics are presented in an organized manner with only a few minor flaws. The handout(s) is/are mostly well written with only a few minor flaws and contained the important information needed to make it useful. The handout included an adequate bibliography for further study. Most of the criteria contained in the Evaluation Form are rated as Excellent or as Very Good by class members and the instructor.

- <u>Excellent (5.0)</u>: The presentation is very appropriately related to the assigned Mini Lesson topics or Engineering Design Challenge process; and reflects a thorough research and innovative preparation effort as evidenced through the content presented and in the supporting handout(s). The PowerPoint presentation file is comprehensive, well-constructed, and developed by presenters to guide their part of the presentation; and contains very relevant and appropriate content topics with enough details to support the selected topic. An introduction is used to capture the attention of class members, a variety of educational technology and presentation techniques are used to enhance learning and a “hands-on” activity is used to involve the class during the presentation. The topics are presented in an organized manner with no noticeable flaws. The handout(s) is/are well written and contain(s) content presented in sufficient detail that will enable readers to apply important information to an assessment problem or activity; and contain(s) a substantial bibliography of references for additional reading. The presentation stays within the appropriate time limit (20 minutes Maximum) and is presented professionally. Questions and comments are made by the audience following the presentation. Almost all of the criteria contained in the Evaluation Form are rated as Excellent or as Excellent by class members and the instructor.

2. **<u>Evaluation Criteria for Engineering Design Challenge</u>:** The final design solutions for the Engineering Design Challenge projects should reflect the standards below, which draw reference from *Engineering Design Challenge – Middle and High School* (Source: http_www uwstout.edu_stem_skillsusa_loader). The Total Credit for this part of the course is 30.0 Points Subtotal (out of 100.0 Points for all course works). Use Engineering Design Challenge Evaluation Form (Appendix EDC-EF).

- **General Standards**: (5.0 Point Subtotal)
  - Innovative Design Solution: 1 Point Subtotal.
    - Solution Defined and Supported by Data: Data includes those collected, measured, or computed (0.5 Point Subtotal);
    - Original/Important Insights of Solution: The design solutions should be substantially different to those available in the market-place (0.5 Point Subtotal).
  - Technologically Feasible: 1.0 Point Subtotal.
    - Manufacturing: The design solutions should lead to the most cost-effective process (0.5 Point).
    - Assembly: The design solutions should lead to the most cost-effective process (0.5 Point).
  - Operationally Viable (Ergonomics): 1.0 Point Subtotal
    - Safety: The design solutions should offer end users a risk-free experience (0.5 Point).
    - Usage and maintenance: The design solutions should offer end users maximum degrees of comfort and convenience possible (0.5 Point).
  - Capable of Accommodating Emerging Needs (Upgradeability): The design solutions should be able to accommodate additional attachments to be designed in the future. 2 Points Subtotal.
    - Potentiometer: With as large a range of resistance as feasible (1.0 Point).
    - Electro-thermal Interface: Ability to accommodate as many types of food cooking container attachments as possible (1.0 Point).
- **Specific Standards:** 15.0 Points Subtotal.
  - Creative Presentation (Presentation): 2.0 Points Subtotal.
    - Unique/Different Presentation Style: Try not to use “traditional” flat rectangular shapes for display panels (0.5 Point).
    - Incorporated Problem, Research & Solution into Effective Presentation: Use arrows, colors and other graphic tools to show

the design activity sequence. The presentation should clear communication and explain technical process related to the engineering innovation and design challenge. (0.5 Point).

- Overall Impact of Presentation: Each Student Group will offer a part of Final Design Presentation while other Groups of students and the instructors make assessment using Evaluation Forms (0.5 Point).

- Evidence of Collaborative Teamwork during Presentation: Based on the flow of presentation from one student to the next. Each student must take an equitable role during the allotted time. (0.5 Point).

- Research Quality (Design): 3.0 Points Subtotal.

  - Data Collection and Supporting Materials: From reports on design activities (Mini Lesson A: 1. Group and Company Report on Existing Products; 2. Group and Company Report on Heat Transfer Computations; 3. Group and Company Report on Potentiometer Design and Testing; 4. Group and Company Report on Design of New Food Cooking Electro-Thermal Interface and Food Containers; and Mini Lesson B. Group and Company Report on Material Selection and Suppliers) (1.0 Point).

  - Data Utilization & Analysis: From the same reports on design activities (1.0 Point).

  - Visual Aids & Overall Design: Mock-up quality, etc. (1.0 Point).

- External Stakeholders (Community, Business & Industry): 2.0 Points Subtotal.

  - Integration of Community, Business & Industry: Throughout the entire Engineering Design Challenge, students should analyze real social needs and impact of their design decision-making on ecology, and record their thought and decisions in the Group and Company Report on Existing Products and in the Engineering Notebook (1.0 Point).

  - Involvement of Community, Business & Industry: During Market Research activities in Mini Lesson A, students should discuss the design project with sales manager, consumers and others; get technical assistance of experts in the field; and take and record their feedback and advice in the Group and Company Report on Existing Products and in the Engineering Notebook. If possible, write a news article to share with the community, through one media form of publicity (such as a local newspaper, a school district newspaper or newsletter, or possibly TV or radio coverage), and one form of public venue (such as girl scouts, boy scouts, school board meeting, or community service group meeting) (1.0 Point).

- Poster Display Quality (Table Display): 3.0 Points Subtotal.
  - Effectiveness of Poster Display Design: General layout, appropriate usage of graphics, color, fonts and sizes for titles and subtitles, and for body texts. The poster display must be contained within a 48”wide x 48” high area. (1.0 Point).
  - Creativity & Innovation of Display: General design of the display (1.0 Point).
  - Appearance & Quality of Display: Quality of the fabrication of the display (1.0 Point).
- Organized Engineering Notebook (Design Notebook): 3.5 Points Subtotal.
  - Executive Summary: At the end of the Engineering Notebook (0.5 Point).
  - Problem Solving Steps Followed: Records showing that both linear and recursive sequences of NCETE High School Engineering Design Process are followed (0.5 Point).
  - Team Member Responsibilities, Roles & Contributions: Recorded in the Learning Log and by the checker’s signatures placed on each page of the Engineering Notebook (0.5 Point).
  - Evidence of Research Conducted: Records of website and supplier addresses, emails and phone numbers (0.5 Point).
  - Brainstorming Documentation: Dated sketches on Engineering Notebook with (1) graphics; (2) notes; and (3) dimensions (if applicable) (0.5 Point).
  - Possible Solution Descriptions/Illustrations (including concise evaluation of merits of each): Notes and sketches recorded during group meetings on Engineering Notebook (0.5 Point).
  - Final Solution Detailed Description (including assessment of societal, economic, and environmental impacts): Attached CAD drawings on Engineering Notebook (0.5 Point).

- Global Climate Problem (Team Problem Solving Activity): 1.5 Points.
  - Ability to Work As A Team: Through Instructors' observation and student feedbacks (0.5 Point).
  - Use of Prior Knowledge: From computations recorded in reports on engineering design activities (0.5 Point).
  - Problem Solving Approach: Through Instructors' observation and records made in Engineering Notebook (0.5 Point).

- For Engineering Design Challenge Portfolio: 5.0 Points.

Directions: (1) Each student should assemble a professional looking Engineering Design Challenge Portfolio, in a 1.0 inch thick 3-ring binder to keep for future personal reference; and (2) the whole class should submit a duplicate to the instructors for future students. Both will be due the last week of the course. Use Engineering Design Challenge Portfolio Evaluation Form (Appendix EDC-EF).

Standard: The portfolio should be packaged in an attractive and sturdy 3-ring plastic binder with a clear plastic cover to contain a printed page with logistical information (name, degree program, course, semester) describing the student. It should have a table of content and be arranged into tabbed sections to facilitate search for information. It should include: (1) reports on design activities; (2) reflection papers; (3) PowerPoint presentation printouts and handouts; (4) Collection of Design Aesthetic Samples (if selected as home work option; (5) logo or packaging design sketch and report; (6) CAD drawings; (7) list of reference sources; (8) list of material suppliers; and (9) graded quizzes. Rubrics will be completed for each assignment by the portfolio developer as a means of self-assessment and placed with each assignment.

Scoring Rubric:

- Not Observed: The portfolio is packaged in a somewhat ragged 3-ring notebook which contains an outside or inside cover page with limited logistical information. Some required portfolio components are typed, most are poorly written, components are poorly organized with no colored dividers or tabs, and the portfolio includes mostly brief and uninformative reflection papers. A table of content is not included to guide the reader through portfolio materials. No effort is made to enhance the appearance of the portfolio. Some portfolio components are self-assessed using rubrics.

- Basic (1.0): The portfolio is packaged in an attractive, 3-ring notebook which contains an outside or inside plastic cover page with logistical information. Most required portfolio components are typed, some are well-written, components are somewhat organized with colored dividers but no tabs, and the portfolio includes brief and not very thoughtful reflection papers and reports. A table of content is included to guide the reader through portfolio materials. Little effort is made to enhance the appearance of the portfolio with color or artwork. Some portfolio components are self-assessed with rubrics.

- Fair (2.0): The portfolio is packaged in an attractive, quality 3-ring notebook which contains a clear plastic cover page with logistical information. All required portfolio components are typed, most are well-written, components are somewhat organized with tabbed dividers and the portfolio includes mostly thoughtful and somewhat comprehensive reflection papers and reports. Some other required items, such as CAD drawings, are included. A table of content is included to guide the reader through portfolio materials. Some creative artwork or thought provoking quotes are used to enhance the appearance of the portfolio. Most portfolio components are self-assessed with rubrics.

- Good (3.0): The portfolio is packaged in a quality 3-ring notebook which contains a clear plastic cover with logistical information. All required portfolio components are typed, well-written, very well organized with tabbed dividers and the portfolio includes thoughtful, extensive reflection papers as well as well-organized and written reports on design activities. Most of other required items, such as CAD drawings and Engineering Notebook pages, are included. A table of contents is included to guide the reader through portfolio materials. Creative art work or though provoking quotes are used to enhance the appearance of the portfolio. All portfolio components are self-assessed with rubrics/rating scales.

- Very Good (4.0): The portfolio is packaged in a quality 3-ring notebook which contains a clear plastic cover with logistical information. All required portfolio components are typed, well-written, very well organized with tabbed dividers and the portfolio includes thoughtful, extensive reflection papers as well as well-organized and persuasive reports on design activities. Almost all of other required items, such as CAD drawings and Engineering Notebook pages, are included. A table of contents is included to guide the reader through portfolio materials. Creative art work or though provoking quotes are used to enhance the appearance of the portfolio. All portfolio components are self-assessed with rubrics/rating scales.

- Excellent (5.0): The portfolio is packaged in a quality 3-ring notebook which contains a clear plastic cover with logistical information. All required portfolio components are typed, well-written, very well organized with tabbed dividers and the portfolio included thoughtful, extensive reflection paper, as well as well-organized and persuasive reports on design activities. All of other required items, such as CAD drawings and Engineering Notebook pages, are included. A table of contents is included to guide the reader through portfolio materials. Creative art work or though provoking quotes are used to enhance the appearance of the portfolio. All portfolio components are self-assessed with rubrics/rating scales.

3. **Standards for the Collection of Design Aesthetics Samples**: 5.0 Points

Directions: (1) students who select this as an option for home work will assemble the collected samples in a 1.0 inch thick 3-ring binder to keep for future personal reference; and (2) All students selecting this option should submit a duplicate to the instructors for future students. Both will be due the last week of the course. Use the Collection of Design Aesthetics Samples Evaluation Form (Appendix CDAS-EF).

Standard: The collection should be packaged in an attractive and sturdy 3-ring plastic binder with a clear plastic cover to contain a printed page with logistical information (name, degree program, course, semester) describing the student. It should have a table of content and be arranged into tabbed sections to facilitate search for information. It should include samples collected from all students involved in the activity: (1) printouts of two-dimensional art and design samples (logo design, paintings, textile patterns, advertisement, etc.), with hand-written or typed notes; (2) printouts of three-dimensional art and design samples (architecture, sculpture, landscapes, packaging, etc.), with hand-written or typed notes; (3) copies of sketches and write-ups related to the logo and packaging designed in this Engineering Design Challenge; (4) list of reference sources. Rubrics will be completed for each assignment by the portfolio developer as a means of self-assessment and placed with each assignment.

Scoring Rubric:

- Not Observed: The collection is packaged in a somewhat ragged 3-ring notebook which contains an outside or inside cover page with limited logistical information. Some notes are typed, most are poorly written; notes are poorly organized with no colored dividers or tabs. A table of content is not included to guide the reader through the samples. No effort is made to enhance the appearance of the collection.

- Basic (1.0): The collection is packaged in an attractive, 3-ring notebook which contains an outside or inside plastic cover page with logistical information. Most notes are typed, some are well-written, somewhat organized with colored dividers but no tabs. A table of content is included to guide the reader through samples. Little effort is made to enhance the appearance of the collection with color or artwork.

- Fair (2.0): The collection is packaged in an attractive, quality 3-ring notebook which contains a clear plastic cover page with logistical information. All notes are typed, most are well-written, and somewhat organized with tabbed dividers. A table of content is included to guide the reader through portfolio materials. Some creative artwork or thought provoking quotes are used to enhance the appearance of the portfolio.

- Good (3.0): The collection is packaged in a quality 3-ring notebook which contains a clear plastic cover with logistical information. All notes are typed, well-written, well organized with tabbed dividers and the collection includes a thoughtful and extensive summary paper, which compares and analyzes many issues related to design aesthetic, in either two-dimensional or three-dimensional design. A table of contents is included to guide the reader through portfolio materials. Creative art work or though provoking quotes are used to enhance the appearance of the portfolio.

- Very Good (4.0): The collection is packaged in a quality 3-ring notebook which contains a clear plastic cover with logistical information. All notes are typed, well-written, very well organized with tabbed dividers and the collection includes two thoughtful and extensive summary papers, which compares and analyzes many issues related to design aesthetic, in two-dimensional and three-dimensional designs respectively. A table of contents is included to guide the reader through portfolio materials. Creative art work or though provoking quotes are used to enhance the appearance of the collection.

- Excellent (5.0): The collection is packaged in a quality 3-ring notebook which contains a clear plastic cover with logistical information. All notes are typed, very well-written, very well organized with tabbed dividers and the collection includes two thoughtful, extensive, well-organized and persuasive summary papers, which compares and analyzes many issues related to design aesthetic, in two-dimensional and three-dimensional designs respectively. A table of contents is included to guide the reader through portfolio materials. Creative art work or though provoking quotes are used to enhance the appearance of the collection. Some original sketches completed by students doing the home work are also included to show students' ability to apply what is learned during the investigation.

4. **Standards for the logo and packaging design**: 5.0 Points for each.

- Ideation Sketch: At least 2 rough main ideas; and 2 enhanced ideas based on 1 selected idea (2.0 Points). Use Logo and Packaging Design Evaluation Form (Appendix L&PD-EF).

- Write-up: Clearly explain the meaning and function of the design, in terms of selection of shapes, colors, lines, and graphics, etc. (1.0 Point).

- Final Design: Professionally designed (using Photoshop, and other software if available), printed with color printer, and fabricated (the logo should be framed or pasted onto a foam core board; the scaled model of the packaging with graphics should be made (2.0 Point).

5. **Standards for Grading Quizzes:** There are 3 Quizzes total, each is worth 5 Points. Each Quiz can be composed of (1) 8 Multiple-Choice and 2 True and False question; (2) 6 Multiple-Choice, 2 True and False question and 2 Fill-in problems; or (3) 2 Multiple-Choice, 2 True and False question, 2 Fill-in problems, and 2 worked-out problems. The time limit is 20 minutes maximum. The Score Breakdowns are as follow:

- Multiple-choice: 4 choices to choose from. Checking 1 wrong answer or failing to check 1 correct answer causes the loss of 1/8 Point.

- True and False: 2 choices to choose from. Checking the wrong answer of ½ Point.

- Fill-ins: 2 banks to fill in. Filling in 1 wrong answer or leaving the blank empty causes the loss of ¼ Point.

- Work-out problems: Each problem is worth 1 Point. Correct use of formula is worth ½ Point; correct use of units is worth ¼ Point; and correct calculation result is worth ¼ Point.

Statistics Analysis on Evaluation and Assessment of Student Performance

Student performance will be statistically analyzed to provide reference for curricular and pedagogic improvements in the subsequent semesters.

Table 7. Student Performance Statistics

Reflection Papers on Mini Lessons (5.0 Points Each)					
Item	**Mean**	**Median**	**Mode**	**Standard Deviation**	**Standard Variance**
Material Selection (5 Pts)					
Design Aesthetics & Graphic Presentation (5 Pts)					
Group and Company Report Reports Related to Engineering Design Challenge (5.0 Points Each)					
Item	**Mean**	**Median**	**Mode**	**Standard Deviation**	**Standard Variance**
Existing Products (5 Pts)					
Heat Transfer Computations (5 Pts)					
Potentiometer Design and Testing (5 Pts)					
Design of New Food Cooking Electro-Thermal Interface and Food Containers (5 Pts)					
Material Selection and Suppliers (5 Pts)					
PowerPoint Presentations (including Concept Maps and Final Design Presentation) (5.0 Points Each)					
Item	**Mean**	**Median**	**Mode**	**Standard Deviation**	**Standard Variance**
PowerPoint presentation: Material Selection (5 Pts)					
Concept Maps: Industrial Product Design (5 Pts)					
Design Presentation (Incorporation of Principles of Ergonomics and User Safety) (5 Pts)					
Concept Maps or PowerPoint Presentation on Manufacturing and Engineering Economics (5 Pts)					

Table 7. Continued.

Engineering Design Challenge (30.0 Points Subtotal)					
General Standards: (5.0 Point Subtotal)					
Item	**Mean**	**Median**	**Mode**	**Standard Deviation**	**Standard Variance**
Innovative Design Solution: 1 Point					
Technologically Feasible: 1.0 Point					
Operationally Viable (Ergonomics): 1.0 Point					
Capable of Accommodating Emerging Needs (Upgradeability): 2 Points					
Specific Standards: 15.0 Points					
Creative Presentation (Presentation): 2.0 Points					
Research Quality (Design): 3.0 Points					
External Stakeholders (Community, Business & Industry): 2.0 Points					
Poster Display Quality (Table Display): 3.0 Points					
Organized Engineering Notebook (Design Notebook): 3.5 Points					
Global Climate Problem (Team Problem Solving Activity): 1.5 Points					
Engineering Design Challenge Portfolio (5.0 Points)					
Item	**Mean**	**Median**	**Mode**	**Standard Deviation**	**Standard Variance**
Engineering Design Challenge Portfolio: (5 Pts)					
Collection of Design Aesthetics Samples (5 Pts)					
Logo design (5 Pts)					
Packaging design (5 Pts)					

Table 7. (Continued)

Quizzes (5.0 Points)					
Quiz A (Electricity and Heat Transfer) (5 Pts)					
Quiz B (Material Selection and Selection) (5 Pts)					
Quiz C (Design Aesthetics and Graphic Presentation) (5 Pts)					
Quiz D (Industrial Product Design) (5 Pts)					
EXTRA CREDITS					
Item	**Mean**	**Median**	**Mode**	**Standard Deviation**	**Standard Variance**
Completing CNC Prototyping (10 Pts)	N/A	N/A	N/A	N/A	N/A
Break-Even Chart Exercise (5 Pts)	N/A	N/A	N/A	N/A	N/A

Chapter 8:

Opportunities for Extension

Overview of the Opportunities for Extension (Additional Mini Lessons) within the Same Engineering Design Challenge

As mentioned in Chapters 1 (pp. 14-16), the 6-week Primary Design Challenge (Mini Lesson A - Physics for Scientist and Engineers) will constitute only the first part of the one-semester-long capstone engineering design experience. Upon completion of the Mini Lesson A, students will proceed to Mini Lessons B through E to complete the whole design process.

There are similarities and differences between Mini Lessons A and Mini Lessons B through E.

Similarities: Some items in the following areas are similar across all Mini Lessons; and they will all apply to Mini Lessons B through E; but their descriptions will be omitted from the descriptions tables of the Mini Lessons B through E (pp. 115-163).

- Introduction:
  - Unit Title: "Multi-functional Food Cooker Design Challenge" (for the entire one-semester capstone experience);
  - Description of the Learners: Same across all Mini Lessons (senior-year students in the proposed B.S. in Engineering and Technology Education for UGA; or high school graduation-year (Grade 12) students in the proposed K-12 Engineering and Technology Education program);
  - Context of the Unit: Same across all Mini Lessons; and each Mini Lesson is to be started upon completion of the previous one.
- Performance Task:
  - Teacher-Directed Evidence (i.e., Quizzes/Tests and Prompts): Same formats to be used across all Mini Lessons (refer pp. 115-163 for details);
  - Observations (What will be observed and recorded?): Some instruments of observation to be used across all Mini Lessons (refer pp. 115-163 for details).
- Possible and Acceptable Media and Materials:

- Content Media: Similar types of Content Media to be used across all Mini Lessons (refer pp. 115-163 for details).

- Possible and Acceptable Teaching Methods:

  - Presentation Formats: Similar across all Mini Lessons (refer pp. 115-163 for details);

  - Scaffolding Strategies: Similar across all Mini Lessons (refer pp. 115-163 for details);

  - Methods of Emphasizing critical information and relationships: Similar across all Mini Lessons (refer pp. 115-163 for details);

  - Flexible Groupings and Peer Support: Similar across all Mini Lessons (refer pp. 115-163 for details);

  - Methods of Providing descriptive feedback: Similar across all Mini Lessons (refer pp. 115-163 for details).

Differences:

- Focus of instruction:

  - Mini Lesson A: Reviewing specific STEM content knowledge and conducting engineering analytic and predictive design, fabrication and testing activities (Refer to Chapters 1 through 6 for details).

  - Mini Lessons B through E: Applying generic knowledge and skills to solve engineering and product design problem in a holistic way, by integrating all relevant factors (social, ecological, economic, artistic, ergonomic, and others. Refer to pp. 115-163 for details).

- Model of engineering design process:

  - Mini Lesson A: “Analytic Reduction” (reverse engineering, using specific tools, formulas, etc). A single-disciplinary approach.

  - Mini Lessons B through E: “System Thinking” (applying generic guidance, knowledge and skills from to solve the design problem in an integrative way. An interdisciplinary approach.

- Methodology of learning:

  - Mini Lesson A: Students will review the previously learned knowledge content, learn relevant new ones, and apply them in a simple engineering analysis and design mini-project (the potentiometer). Three methods to be used: (1) pen-and-pencil computations using formulas; (2) digital simulation with software (Electronics Workbench); and (3) lab testing and fabrication.

- Mini Lessons B through E: Students will study and apply generic knowledge and skills to help solving the design problem. Internet search for relevant knowledge and resources (such as suppliers of materials) will be extensively conducted.

Class Schedule

Refer to Chapter 1 (pp. 24-26).

Mini Lesson B.

Material Selection

Introduction

Content/Topic Area(s)	Material Selection
Time Frame	Weeks 7 - 9 (3 weeks total).
Description of the Learning	Students will learn: • <u>Properties and applications of materials.</u> • <u>Material selection digital technology</u>: Relevant tools in Granta Material Intelligence software will be reviewed or taught to help students to select materials; • <u>Internet search</u>: Relevant Internet sources will be explored to locate suppliers of engineering materials, with full classroom lecture and demonstration, or in individual or group coaching/tutoring.

Learning Results

Content Area(s)	Material Selection
Standard Label(s)	*Standards B. Material Selection*
Standard(s) & Descriptor(s)	**Students will understand that different materials have different physical properties, which allow them to be used for different purposes (such as thermal conduction, electrical conduction or insulation).** *Properties and applications of different types of metasl, plastics and ceramics will be studied; and Internet and library will be explored for locating suppliers of materials relevant to the design project. The instructor will coach students to conduct these activities.*
Performance Indicator(s)	*Students should learn* *1. The properties of metal, plastic and ceramic materials.* *2. The applications of metal, plastic and ceramic materials.* *3. The availability of metal, plastic and ceramic materials.*

Desired Results: Content and Performance Standards

B-I-A. What key *knowledge* and *skills* will learners acquire as a result of this Mini Lesson?

Learners will know: (Content Standards)	*Metal materials can be used for conducting electricity and heat.* *Plastics can be used as electrical insulator.* *Ceramic can be used as material for food container.*
Learners will be able to: (Performance Standards)	*Students should learn to* *1. Select appropriate materials (metal, ceramic and plastics) for different parts of the multi-functional food cooker, based on understanding of the knowledge content in the previous Material Selection course and in the instructor's Mini-Lesson lectures, as well as on the application of materials in the existing products in the market, found through the reverse engineering investigation process. Granta Material Intelligence software can be used.* *2. Locate suppliers of the selected materials through local store, library and Internet searches.* *3. Analyze the properties, qualities and prices of available materials using Comparison Charts (in Appendix B2), and make decision on material purchase for the design project's working prototype.*

B-I-B. What *enduring understandings* are desired?

Students will understand that:	*Different types of materials have different thermal and electrical properties, which can be used to satisfy different requirements of different components in a product or system.*

B-I-C. What *essential questions* will guide this Mini Lesson and focus teaching and learning?

Teacher-generated Essential Questions:	*1. What are the common or similar characteristics of all materials?* *2. Why there are major differences in physical properties among different types of materials?* *3. How can these differences in physical properties among different types of materials be used to achieve engineering design objectives?* *4. For a sustainable economic growth, what types of materials should be used as much as possible in product design, and why?*
Learner-generated Essential Questions:	*1. What are the major differences among metal, ceramic and plastic materials, in terms of their molecular structures?* *2. How do the differences in molecular structures affect the physical properties of metal, ceramic and plastic materials?* *3. What are the fundamental differences between thermosetting plastics and thermoplastics?*

B-II-A. Possible and Acceptable Sources of Evidence of Student Learning

Performance Task

The Performance Task is based on the above four Teacher-generated Essential Questions and three Learner-generated Essential Questions. Each student will select one of the above four questions. Two home works will be assigned:

1. Understanding of knowledge content: students will choose either one of the following two options as the choice for the first assignment.

- Write a Reflection Paper on Material Selection Mini Lesson to reflect upon his/her chosen question, to record thoughts, beliefs, and understandings as they evolve and change over time, with self-designed tables, graphs, concept maps and other visual elements. The paper should be doubled-spaced, with a limit of 10 pages maximum; should include: (1) explanation of the most important principles and/or knowledge of materials science learned in the Mini Lesson, in comparison to previous assumption; (2) the way these principles are reflected in the existing food cooking device design (i.e., how are different types of materials used in the existing products studied in the reverse engineering activity during the Mini Lesson A); (3) the way these principles and/or knowledge will be applied in the one-semester long design project, and in the future design activities; (4) any personal thoughts, comments and suggestions on the organization of the course materials and on the delivery of knowledge content by the instructor; and (5) references.

- Make a PowerPoint presentation file to demonstrate their critical thinking and understanding of the most important principles of materials science and its practical applications in engineering design. Limit the number of slides to 10. The PowerPoint should include: (1) list of the most important principles of materials science learned in the Mini Lesson (include images, tables, graphs, concept maps, video clips if relevant); (2) examples that help illustrate the principles, with relevant graphs (pictures from Internet, or scanned sketches or pictures); (3) application of these principles in real-world engineering design; and (4) reference. Include handout(s) if needed. Handout(s) can be written by the students, or printed copies of relevant web pages or of books (do respect the “fair use” provision of copyright laws, i.e., non-profit educational use with only enough copies for the classmates, and only a few pages from each chapter).

2. Application of Knowledge content: Each student from groups of three students will separately work on selection of engineering materials needed for the design challenge using Granta Material Intelligence program, and on locating suppliers through Internet search and other means, on one of the three major types of materials (metals, plastics, and ceramics). Each student will write his/her portion of the Report on Material Selection with Granta Material

Intelligence and Through Internet Search. The Group Coordinators will then assemble all portions into the group report, which will be sent to the Company Coordinator. The Company Coordinator will analyze and compare the results of each group, make the final decision on the selection of the most appropriate materials and suppliers based on quality, financial and other criteria, and create a final Company Report on Material Selection and Suppliers to be submitted to the instructor for approval. For the writing template, see Appendix B2.

Student Collaboration**:** The whole class will be randomly divided into groups of three students, and one group member will be randomly elected as the Group Coordinator to coordinate group activities. The Group Coordinators will select by lottery a Company Coordinator to coordinate the works of all groups.

Upon completion of the assignment, each student will email it to the instructor and other students for information sharing and peer review/critique.

B-II-B. Possible and Acceptable Media and Materials

Instructional Materials	The following instructional materials will be used: • Granta Materials Intelligence materials selection software; • PowerPoint presentation; • Videos from Internet (primarily from http://www.youtube.com. See Chapter 9 (pp. 172-173) for a list.

Classroom Sessions

Sessions 1 and 2: Material Properties and Applications (Lecture, Internet Video Show, Sample Display)

These Sessions can be completed in two class period. If additional time is needed, after-school time as well as part of the next Session can be used to complete the assignment.

Overview:

These Sessions will review knowledge content relevant to the application of materials in engineering design; and the topics will include:

1. Chemical structures of atoms in metal (steel, aluminum, copper, etc.), plastics and ceramic materials;

2. Properties of the above types of materials and their application in engineering design (with examples in some case studies);

Goals:

Students will, under the guidance of the instructor,

- Review the fundamental chemical structures of atoms in metal (steel, aluminum, copper, etc.), plastics and ceramic materials;
- Conduct additional study the various properties of the above types of materials and their application in engineering design (through Internet search); and record the relevant data in the Reflection Paper on Material Selection Mini Lesson, or PowerPoint presentation.

Materials:

- Computer with projector and screen;
- Samples of metal (steel, aluminum, copper, etc.), plastics and ceramic materials;
- Handouts on materials properties and application (Appendix B1b).

Detailed Steps:

1. PowerPoint presentation with data tables, graphics and pictures, and Internet video show.

   Lecture presentation or Internet video show (20 minutes each) will be followed by a Question-and-Answer period (10 minutes each).

2. Under the guidance of the instructor, students will conduct relevant online search activities for additional information on material properties and application; and record the results in the Reflection Paper on Material Selection Mini Lesson, or PowerPoint presentation.

   The instructor will provide in-class coaching and tutoring.

A Note about the lecture:

The instructor will spend most of lecture time on the properties and applications of relevant materials in engineering design. The instructor will prepare a list of Website links and Youtube video on industrial materials and e-mal it to students before the start of the Sessions, for students to study before and after the Sessions. For a list of Websites and Youtube videos, refer to Chapter 9, pp. 172-173).

Sessions 3: Granta Materials Intelligence (Tutorial), and

Sessions 4: Granta Materials Intelligence (Material Selection Exercise)

These Sessions can be completed in two class periods. If additional time is needed, after-school time as well as part of the next Session can be used to complete the assignment.

Overview:

These Sessions will teach students relevant skills in using Granta Materials Intelligence software, for the selection of engineering materials. Topics will include:

1. User Graphic Interface;
2. Settings and Options;
3. Particular tools relevant to this Engineering Design Challenge;
4. The Help menu for locating additional information.

Goals:

Students will, under the guidance of the instructor,

- Learn the basic User Graphic Interface, Settings and Options, and the Help menu in Granta Materials Intelligence software;
- Learn the particular tools for locating metal (steel, aluminum, copper, etc.), plastics and ceramic materials that are relevant to this Engineering Design Challenge.

Materials:

- Computer with projector and screen;
- Granta Materials Intelligence software;
- Handouts on Granta Materials Intelligence Tools (Appendix B1c).

Detailed Steps:

1. Launching the Granta Materials Intelligence software; demonstrating the User Graphic Interface, Settings and Options, and the Help menu.

Software presentation (15 minutes) will be followed by a student practice using instructor-supplied Handouts on Granta Materials Intelligence Tools (Appendix B1c) (20 minutes).

2. Granta Materials Intelligence tools for selection of relevant metal (steel, aluminum, copper, etc.), plastics and ceramic materials for this Engineering Design Challenge.

   Software presentation (30 minutes) will be followed by a student practice using instructor-supplied step-by-step information sheet (Appendix B1c). (40 minutes).

3. Additional time for further practice with the software (students should be advised to repeat the same practice twice or three times in order to master the tools).

A Note about the lecture:

The instructor will spend sufficient amount of time tutoring students during classroom practice on the software.

Sessions 5 and 6: Granta Materials Intelligence (Material Selection for the Design Challenge)

These Sessions can be completed in two class period. If additional time is needed, after-school time as well as part of the next Session can be used to complete the assignment.

Overview:

These Sessions will coach students on the relevant Granta Materials Intelligence software tools, for the selection of engineering materials. Topics will include:

1. Selection for metal materials;

2. Selection for plastic materials;

3. Selection for ceramic materials.

Goals:

Students will, under the guidance of the instructor, use particular tools in Granta Materials Intelligence software to select appropriate materials for this

Engineering Design Challenge, and record the results in the Report on Material Selection and Suppliers:

- Metal materials (steel, aluminum, and others);
- Plastics (thermosetting, etc.);
- Ceramics.

Materials:

- Computer with projector and screen;
- Granta Materials Intelligence software;
- Handouts on Granta Materials Intelligence Tools (Appendix B1c).

Detailed Steps:

1. Launching the Granta Materials Intelligence software; review the User Graphic Interface, Settings and Options, and particular tools for selecting metal, plastic and ceramic materials.

   Software presentation (15 minutes) will be followed by a Question-and-Answer time (15 minutes).

2. Watching and tutoring students using Granta Materials Intelligence tools for selection of relevant metal (steel, aluminum, copper, etc.), plastics and ceramic materials for this Engineering Design Challenge.

   The instructor will help students complete the selection process based on student needs

A Note about the lecture:

The instructor will spend sufficient amount of time tutoring students during this vital part of the Mini Lesson.

Sessions 7: Search for Suppliers of Selected Materials Through Internet and School Facility Visit

This Session is designed to help students finding suitable materials for the construction of the functional prototype for the Multi-functional Food Cooker in this Engineering Design Challenge; and it can be completed in one class period. If additional time is needed, after-school time as well as part of the next Session can be used to complete the assignment.

Overview:

This Sessions will coach students on locating materials selected using Granta Materials Intelligence software in Session 5 and 6, through

1. Internet search: For (1) metal materials (using the website of U.S Steels, Inc., at http://www.ussteel.com/corp/index.asp; of the Aluminum Company of America at http://www.alcoa.com/global/en/home.asp); (2) plastic materials (using the website of U.S. Plastics at http://www.usplastic.com/catalog/default.asp, and others). The instructor will explain the activity for 20 minutes and give students handouts on conducting these activities.

2. Visiting school manufacturing and/or construction facilities: The instructor will give an instructional tour to students.

Goals:

Students will, under the guidance of the instructor, conduct the following activities to locate appropriate materials (metals and plastics) for this Engineering Design Challenge, and record the results in the Report on Material Selection and Suppliers:

3. Internet search (at home);

4. School facility visitation (during class time).

Materials:

- Computer with projector and screen;

- Handouts on Internet Search for Materials Suppliers (Appendix B1d).

Detailed Steps:

1. Launching the Internet search engine, and go to relevant websites such as those listed in the Overview section.

   Demonstration on website search (20 minutes) will be followed by a Question-and-Answer time (15 minutes).

2. Visiting school facilities (the remainder of class meeting time).

A Note about the lecture:

The instructor will visit the relevant websites, conduct searches, prepare information handouts, and visit the school's facilities and make arrangement before the Session start.

Session 8: Quiz B (Material Properties and Selection)

This session is for the Mini Lesson B Quiz, a general review of the previous works, and a brief introduction to the Mini Lesson C (Design Aesthetics and Graphic Presentation).

Overview:

The Quiz B will include 8 Multiple-choice and 2 True and False questions, and will test the students on:

1. The fundamentals of chemical structures of atoms (2 Multiple-choice);
2. The most important properties of metal materials, and their application in real world engineering design (2 Multiple-choice);
3. The most important properties of plastic materials, and their application in real world engineering design (2 Multiple-choice);
4. The most important properties of ceramic materials, and their application in real world engineering design (2 Multiple-choice);
5. Material selection in engineering design (2 True and False).

Goals:

Students will,

4. Take Quiz B (15 minutes at the start of the Session).
5. Raise additional questions during the after-test review.

Materials:

6. Quiz B form;
7. White board and markers.

Detailed Steps:

1. Quiz B (15 minutes);

2. Review/critique for student works during Mini Lesson B (20 minutes);

3. Question-and Answer Session (10 minutes);

4. Brief introduction to Mini Lesson C (Design Aesthetics and Graphic Presentation).

A Note about the lecture:

Give student praise for their patience, efforts, and accomplishment so far. Encouraging students to improve learning process (be specific and courteous in explaining the shortcomings observed and new expectations for changes).

Mini Lesson C.

Design Aesthetics and Graphic Presentation

Content/Topic Area(s)	Design Aesthetics and Graphic Representation
Time Frame	Weeks 10 and 11 (2 weeks total).
Description of the Learning	Students would learn: • Basic principles and skill of two-dimensional arts: o Colors: Cultural connotations of colors; cool vs. warm colors and their usage; o Shapes: Regular geometric shapes (circle, ellipse, polygon, triangle, including calculation for areas) vs. irregular shapes. o Photoshop skills: Image, Layer, Select, Eye Dropper, Paint, Text, and other basic tools. o PowerPoint skills: Diagram and Organization Chart, Draw, Arrow, etc. o Company Logo design (extra topic): Basic principles. • Basic principles and skill of three-dimensional arts: o Three-dimensional bodies: Regular shapes (cone, cylinder, cube, pyramid, etc. Including calculation of volumes), and irregular shapes (including the method of finding the volume of irregular shape using a larger container with regular shape). o Three-dimensional mock-up fabrication: Use paper board, foam and foam core, softwood (balsa and pine) and tapes to construct preliminary design mock-ups for physical dimensional studies. o Basic package design and fabrication (extra topic): Using paperboard (for B.S. in K-12 Engineering and Technology Teacher Education Senior-Year students only).

Learning Results

Content Area(s)	Design Aesthetics and Graphic Representation
Standard Label(s)	*Standards C. Design Aesthetics and Graphic Presentation*
Standard(s) & Descriptor(s)	**Students will understand the principles of aesthetics and their applications in two- and three-dimensional designs.** *1. Aesthetics reflect cultural values as well as personal*

	preferences; *2. Aesthetics can be represented by visual elements, such as three-dimensional forms, two-dimensional shapes, colors, lines, etc.;* *3. Aesthetics is an important factor in creativity.*
Performance Indicator(s)	*Students should learn how to* *1. Make the product aesthetically attractive to customers.* *2. Present the design of the product to the clients and to other members in the design team.*

Desired Results: Content and Performance Standards

C-I-A. What key *knowledge* and *skills* will learners acquire as a result of this unit?

Learners will know: (Content Standards)	*Aesthetics is a reflection of cultural values.* *Aesthetics are reflected by the selection of colors, shapes and other visual elements.*
Learners will be able to: (Performance Standards)	*Students should demonstrate their ability to* *1. Select appropriate colors, shapes and other visual elements that can make the design of the multi-functional food cooker visually appealing.* *2. Integrate the appropriate visual elements into the design of the multi-functional food cooker such that the later will be functionally and ergonomically efficient.* *3. Use graphic arts and presentation software (Adobe Photoshop and PowerPoint, etc.) to present creative thought and ideas.*

C-I-B. What *enduring understandings* are desired?

Students will understand that:	*Form follows function.* *Arts reflect cultural values (collective experience vs. personal preference).* *Artistic creativity is both individual and societal (in mass-produced product design, artistic creativity must fall within acceptable cultural frameworks)*

C-I-C. What *essential questions* will guide these units (Mini Lessons) and focus teaching and learning?

Teacher-generated Essential Questions:	*1. Why should form follow function in product design?* *2. Why aesthetics are different across different cultures?* *3. How is aesthetics related to social, economic, political and other factors?* *4. Whose aesthetics values should be applied to product design? To graphic arts? Yours or your clients'? To fine arts? What is the major difference in the application of aesthetic values?*

Learner-generated Essential Questions:	*1. What are the subtle differences in color and shape preferences between Northern European cultures and Mediterranean countries? Between European countries and Asian cultures, African countries, and Native American cultures?* *2. Are there universally accepted aesthetics values? If so, what are they? (Give some examples in terms of colors, shapes, and other visual elements. Explain their cultural connotations).* *3. What is the relationship between personal and societal aesthetic values?* *4. How do aesthetic values evolve with the passage of the time?*

C-II-A. Possible and Acceptable Sources of Evidence of Student Learning

Performance Task

The Performance Task is based on the above four Teacher-generated Essential Questions and the four learner-generated Essential Questions. Each student will select one of the above four questions. Each student will select one of the above four questions. Two home works will be assigned:

1. Understanding of knowledge content: Each student will freely choose either one of the following two options as the choice for the first assignment.

   - Write a Reflection Paper on Design Aesthetics and Graphic Presentation Mini Lesson to reflect upon his/her chosen question, to record thoughts, beliefs, and understandings as they evolve and change over time, with self-designed tables, graphs, concept maps and other visual elements. The paper should be doubled-spaced, with a limit of 10 pages maximum; should include: (1) explanation of the most important principles and/or knowledge of two-dimensional and three-dimensional arts learned in the Mini Lesson, in comparison to previous assumption; (2) the way these principles are reflected in the existing food cooking device design (i.e., how are different colors, shapes, and graphics used in the existing products studied in the reverse engineering activity during the Mini Lesson A); (3) the way these principles and/or knowledge will be applied in the one-semester long design project, and in the future design activities; (3) any personal thoughts, comments and suggestions on the organization of the course materials and on the delivery of knowledge content by the instructor; and (4) references.

   - Assemble a Collection of Design Aesthetics Samples (printed two-dimensional arts and/or pictures of three-dimensional arts) to demonstrate his/her understanding of the question, with notes, handwritings, and other explanatory elements. The collected artworks should be neatly placed in a three-ring bundle (0. 5 to 1 inch thickness) with dividers, tabs and handwritten or typed notes. Instead of a binder, digital portfolio will be accepted.

2. Application of Knowledge content: Groups of three students will choose by lottery one of the following three options as the choice for the second assignment. Each group will work on their choice collaboratively.

   - Logo Design: Propose a name for the company that will manufacture the multi-functional food-cooking device (consider the whole class as a single company), and design the company logo (requirements: ideation sketch and notes on the symbolic significance of the logo on Engineering Notebook, Photoshop digital file and hardcopy).

   - Packaging Design: Design a paperboard package for new product using the chosen dimensions (length x wide x height) as the basic constraint. Requirements: ideation sketch (flat pattern plus isometric or oblique view), and notes on Engineering Notebook; scale-down (1:10) model (made in cardstock paper).

   - Final Design Presentation: During this Mini Lesson, students will incorporate principles of design aesthetics into the design of the exterior of the multi-functional food cooking device. In the Final Design Presentation (PowerPoint, 15 slides maximum), students will dedicate at least one slide to explain how knowledge contents from the Design Aesthetics and Graphic Presentation Mini Lesson are applied in the final design.

     Student Collaboration**:** Same as in Mini Lesson B.

Upon completion of the assignment, each student will email it to the instructor and other students for information sharing and peer review/critique.

C-II-B. Possible and Acceptable Media and Materials

Instructional Materials	The following instructional materials will be used: • Samples of two-dimensional and three-dimensional artworks: From Internet, textbook, $1.00 stores, and other sources. • Presentation software: Microsoft PowerPoint and Adobe Photoshop. • Videos: From Internet. See Chapter 9 (pp. 173-179) for a list.

Classroom Sessions

Session 1: Elements of Aesthetics (Points, Lines, Surfaces, 2D Shapes, 3D Bodies, Colors) and Product Exterior Design

This Session can be completed in one class period.

Overview:

This Session will review and teach general principles of design aesthetics relevant to applied design, and their applications in the design of the exterior part of real world product, in terms of the following visual elements and their cultural and aesthetic connotations:

1. Points: Abstract concept and physical artifacts;

2. Lines: Linear and curved, planar and spatial;

3. Surfaces: Flat, single-curved and double-curved;

4. Colors: Warm, cold, and neutral; shinny, dull and low-shine; complementary and supplementary; shades of gray, etc.;

5. 2D Shapes: Triangle, quadrilateral (square, rectangle, rhombi, parallelogram, etc.), circle and ellipse, polygons, irregulars;

6. 3D Bodies: Pyramid, cube, sphere, ellipsoid, cylinder, cone, etc.

In addition, the evolution of aesthetics and differences in aesthetics preferences among the nations, groups and individuals, will be discussed:

- Personal aesthetic preference versus society norms;

- Fine arts versus applied design;

- Culture-based aesthetic differences versus common human values on aesthetics, in the Age of Globalization.

Goals:

Students will, under the guidance of the instructor,

1. Learn and review the fundamental principles of aesthetics and their application in applied design in general;

2. Learn and review the fundamental principles of aesthetics and their application in consumer product design in particular;

3. Conduct additional study of aesthetic issues by Internet search and/or collection of design samples. Students will choose to write a Reflection Paper on Design Aesthetics and Graphic Presentation Mini Lesson, or make a Collection of Design Aesthetics Samples (preferably in the areas of product, architectural, and graphic or advertising design).

4. Determine how to apply design-related aesthetics principles in the design of the exterior part of the Multi-functional Food Cooker, through selection

of appropriate visual elements; and record design ideas in Engineering Notebook and or the Reflection Paper on Design Aesthetics and Graphic Presentation Mini Lesson.

Materials:

- Computer with projector and screen;
- Samples of fine arts or applied design (pictures from the Internet, prints, and 3D works;
- Handouts on Design Aesthetics (Appendix C1b).

Detailed Steps:

1. PowerPoint presentation with examples of arts and design, or Internet video show.

   Lecture presentation or Internet video show (20 minutes) will be followed by a Question-and-Answer period (10 minutes).

2. Under the guidance of the instructor, students will conduct relevant online search activities for additional information on design aesthetics; and record the results in the Reflection Paper on Design Aesthetics and Graphic Presentation Mini Lesson.

   The instructor will provide in-class coaching and tutoring.

A Note about the lecture:

The instructor will pay attention to using concrete example to explain abstract principles, using a collection of samples.

Session 2: Company Logo Design

This Session can be completed in one class period. If additional time is needed, after-school time as well as part of the subsequent Sessions can be used to complete the assignment.

Overview:

This Session will review and teach general principles of logo and corporate identity design:

1. Functions of corporate identity in product marketing;

2. Fundamentals of company logo design and its relationship with product design (size and location on the product, its literature and advertising);

3. Procedures and skills for company logo design and production (concrete versus abstract imagery; symbolism and application of visual elements; 2D versus 3D logo representation; and static versus animated logos).

Goals:

Students will, under the guidance of the instructor,

4. Understand the basic issues related to corporate identity design;

5. Design a company logo for the Multi-functional Food Cooker.

Materials:

- Computer with projector and screen;
- Samples of company identity (logo) design (pictures from the Internet, prints, and 3D artworks (keychain, pins, etc);
- Handouts on Logo Design (Appendix C1c).

Detailed Steps:

1. PowerPoint presentation with display of examples of logo design.

   Lecture presentation and display (20 minutes) will be followed by a Question-and-Answer period (10 minutes).

2. Under the guidance of the instructor, students who choose logo design as an assignment will conduct step-by-step logo design activities; and record the ideation process and results in the Engineering Notebook:

   - "Brainstorming:" Each student choosing logo design as an assignment will come up with 3 major ideas;
   - Idea sharing: Each student choosing logo design as an assignment will present the 3 major ideas to members of the Student Group for feedback, and decide on 1 best idea to improve;
   - Further ideation: Each student choosing logo design as an assignment will work on the best design, with 3 variations; present it again to other group members for feedback, and decide on the best one as the final design.

- Final selection: All students choosing logo design as an assignment will then present their final logo design in hard copy for all students in the class to select the best for the Company.

The instructor will provide in-class coaching and tutoring.

A Note about the lecture:

The instructor will pay attention to using a collection of logo design samples to show students how they have been used.

Sessions 3 and 4: Product Packaging Design

These Sessions can be completed in two class periods. If additional time is needed, after-school time as well as part of the subsequent Sessions can be used to complete the assignment.

Overview:

These Sessions will review and teach general principles of product packaging design:

1. Functions of product packaging in product marketing;

2. Fundamentals of product packaging design and its relationship with product design (size and types, use of logo, graphics, text, barcode and other elements, materials and production);

3. Procedures and skills for product packaging design and production (3D folded model and 2D flat pattern; descriptive geometry and Autodesk Inventor Sheet-metal Tool Set; production basics).

Goals:

Students choosing packaging design as an assignment will, under the guidance of the instructor,

4. Understand the basic issues related to product packaging design;

5. Design a product packaging for the Multi-functional Food Cooker.

Materials:

- Computer with projector and screen;

- Samples of product packaging design (made in paper, paperboard, plastic, metal, etc);
- Handouts on Packaging Design (Appendix C1d).

Detailed Steps:

1. PowerPoint presentation with display of examples of product packaging design.

   Lecture presentation and display (20 minutes) will be followed by a Question-and-Answer period (10 minutes).

2. Under the guidance of the instructor, students who choose product packaging design as an assignment will conduct step-by-step logo design activities; and record the ideation process and results in the Engineering Notebook:

   - "Brainstorming:" Each student choosing product packaging design as an assignment will come up with 3 major ideas (with sketches of 3D folded model and 2D flat pattern development, plus notes);
   - Idea sharing: Each student choosing product packaging design as an assignment will present the 3 major ideas to members of the Student Group for feedback, and decide on 1 best idea to improve;
   - Further ideation: Each student choosing product packaging design as an assignment will work on the best design, with 3 variations; present it again to other group members for feedback, and decide on the best one as the final design.
   - Final selection: All students choosing product packaging design as an assignment will then present their final product packaging design in hard copy for all students in the class to select the best for the Company.

The instructor will provide in-class coaching and tutoring.

A Note about the lecture:

The instructor will pay attention to using a collection of product packaging design samples to show students how they have been used.

Session 5: Photoshop Tools (Lecture/Demonstration/Exercise)

This Session can be completed in one class period.

Overview:

This Session will review and teach graphic design skills using Adobe Photoshop, which are relevant to the creation of elements of aesthetics covered in Session 1, and to logo and packaging designs covered in Session 2 and 3:

1. Setting and Options;

2. Particular tools in Photoshop: Layer, Selection, Marquee, magic Wand, Paint Bucket, Eyedropper, pen, Text, Make Work Path, Transform, Color Balance, Brightness/Contrast, Hue/Saturation, and others;

3. Using a variety of tools to create special visual effects (feather, Opacity, and others).

Goals:

Students will, under the guidance of the instructor,

1. Learn how to use particular Tools in Photoshop;

2. Learn how to combine a variety of Tools in Photoshop to create special effects in graphic design;

3. Learn how to bring CAD 2D drawing and 3D model screen shots into Photoshop for creating special effects.

4. Apply skill gained from the above steps in creating the final digital version of the logo and product packaging designs.

Materials:

- Computer with projector and screen;

- Samples of graphic design special effects created in Photoshop (pictures from the Internet and prints);

- Handouts on Photoshop Tools (Appendix C1e).

Detailed Steps:

1. Software demonstration on Photoshop Options, Settings, Tools, and special effects.

Software presentation (20 minutes) will be followed by a Question-and-Answer period (10 minutes).

2. Under the guidance of the instructor, students will create the digital versions of their logo and packaging design in Photoshop.

   The instructor will provide in-class coaching and tutoring.

A Note about the lecture:

The instructor will prepare detailed handouts on step-by-step usage of Photoshop tools, options and settings, to help students practice Photoshop tools after the class meetings.

Session 6: PowerPoint Tools (Lecture/Demonstration/Exercise)

This Session can be completed in one class period.

Overview:

This Session will review and teach principles and skills in creating professional-looking PowerPoint presentation files:

1. General design principles: Layout, background and text colors, font and size of titles versus body text, appropriate amount of information per slide, use of graphics, etc.;

2. Setting and Options;

3. Particular tools in PowerPoint: Insert Clip Art, Fill Color, Line Color, Font Color, Rectangle, Oval, Arrow, Line, AutoShapes, etc;

4. Special visual effects in PowerPoint slides: Slide Transition, etc.

Goals:

Students will, under the guidance of the instructor,

1. Learn how to create professional-looking PowerPoint presentation files;

2. Learn how to use special effect tools in PowerPoint;

3. Apply skill gained from the above steps in creating better-quality PowerPoint presentation files through the remainder of the course.

Materials:

- Computer with projector and screen;

- Samples of PowerPoint presentation files;
- Handouts on PowerPoint Tools (Appendix C1f).

Detailed Steps:

1. Software demonstration on PowerPoint Settings, Tools, and special effects.

   Software presentation (20 minutes) will be followed by a Question-and-Answer period (10 minutes).

2. Under the guidance of the instructor, students will create better PowerPoint files for design presentation for the remainder of the Mini Lesson.

   The instructor will provide in-class coaching and tutoring.

A Note about the lecture:

The instructor will prepare detailed handouts on step-by-step usage of PowerPoint tools, options and settings, to help students practice PowerPoint tools after the class meetings.

Session 8: Quiz B (Material Properties and Selection)

This session is for the Mini Lesson C Quiz, a general review of the previous works, and a brief introduction to the Mini Lesson D (Industrial Product Design).

Overview:

The Quiz C will include 8 Multiple-choice and 2 True and False questions, and will test the students on:

1. The fundamentals design aesthetics (2 Multiple-choice);
2. Elements of aesthetics and their cultural connotations (2 Multiple-choice);
3. The most important issues related to corporate identity design (2 Multiple-choice);
4. The most important issues related to product packaging design (2 Multiple-choice);
5. Production of packaging and materials (2 True and False).

Goals:

Students will,

- Take Quiz C (15 minutes at the start of the Session).
- Raise additional questions during the after-test review.

Materials:

- Quiz C form;
- White board and markers.

Detailed Steps:

1. Quiz C (15 minutes);
2. Review/critique for student works during Mini Lesson C (20 minutes);
3. Question-and Answer Session (10 minutes);
4. Brief introduction to Mini Lesson D (Industrial Product Design).

A Note about the lecture:

Give student praise for their patience, efforts, and accomplishment so far. Encouraging students to improve learning process (be specific and courteous in explaining the shortcomings observed and new expectations for changes).

Mini Lesson D.

Industrial Product Design

Content/Topic Area(s)	Industrial Product Design
Time Frame	Weeks 12 and 13 (4 weeks total).
Description of the Learning	Students will further explore: • NCETE High School Engineering Design Process: Techniques of "brainstorming" and "system thinking" will be explained to students (*Figure 8A*, p. 143). • Computer-Aided-Design/Drafting: Relevant additional skills in engineering design and simulation software (such as Autodesk Inventor and Electronics Workbench) will be either reviewed or taught to help students complete the project in a professionally way, with either full classroom demonstration, or in individual or group tutoring. • Product Design related Issues: o Ergonomics: Basic principles will be explored in classroom lecture and group tutoring. o Product Safety: Basic principles will be explored in classroom lecture and group tutoring. o UL (Underwriter Laboratory) Testing: Basic procedures will be introduced in classroom lecture. o Patent Application: Basic procedures will be introduced in classroom lecture.

Learning Results for opportunities for Extension (Additional Mini Lessons)

Content Area(s)	Industrial Product Design
Standard Label(s)	*Standards D. Industrial Product Design*
Standard(s) & Descriptor(s)	**Students will understand the process of industrial product design.** *Industrial product design is a hybrid design process, which include:* *1. Engineering design (using the NCETE High School Engineering Design Process, as shown in Figure 3, as the basic process for product design);* *2. Ergonomics (user safety and convenience); and* *3. Aesthetics (two-dimensional graphics as well as three-dimensional shape of the product. Explored in Mini Lesson C).*

	4. Students will learn how these three components work together, and why industrial product design should *5. Serve legitimate social needs (profit, safety, affordability, etc.); Be ecologically sustainable (multiple functionality, recyclability, standardization, upgradability, etc.)*
Performance Indicator(s)	*Students should learn* *1. How products are designed.* *2. How products are tested and modified.* *Students should be able to* *1. Integrate all relevant factors into a holistic and functional design solution.* *2. Apply the basic principles of product design to complete the design project.*

Desired Results: Content and Performance Standards

D-I-A. What key *knowledge* and *skills* will learners acquire as a result of this unit?

Learners will know: (Content Standards)	*The design process is both linear and recursive.* *Good design involves a balance among several factors (technological, ergonomic, aesthetic, economic, social and ecological).* *Design is a team effort.*
Learners will be able to: (Performance Standards)	*Students should demonstrate their ability to* *1. Conduct additional market research (store visitation and Internet search) and write a statement with an Available Product Comparison Chart, and add it in the Company Report on Existing Products (Appendix A2a).* *2. Record design ideas with sketches, notes, calculations and attached information printouts on in Engineer's Notebook (Appendix EN).* *3. Make three-dimensional digital models and two-dimensional working drawings with Autodesk Inventor or SolidWorks software, and, <u>for B.S. in K-12 Engineering and Technology Education Senior-Year students ONLY as an extra topic</u>: conduct digital simulation of the new design with appropriate software (COSMOS, etc.) if possible.* *4. Write a statement on the design process and the advantage of the new design from the perspectives of functionality, ergonomics, aesthetics, economics, and ecological sustainability, and add it in the Company Report on Existing Products (Appendix A2a).*

D-I-B. What *enduring understandings* are desired?

Students will understand that:	*Good product design must be a well-balanced one (function, technology, ergonomics, aesthetics, economics, and ecology).*

D-I-C. What *essential questions* will guide this Mini Lessons and focus teaching and learning?

Teacher-generated Essential Questions:	*1. How can creativity and rationality be integrated in engineering and product design?* *2. How does product design affect the quality of human life? The protection of the environment? The sustainability of economic growth?* *3. How to balance short-term cost effectiveness and long-term sustainable growth in product design? Are these two factors competing against each other or are they integral parts of the whole corporate strategy?*
Learner-generated Essential Questions:	*1. What are the different roles creative imagination and engineering predictive analysis play in the process of engineering design?* *2. Why the design process is both linear and recursive? How to integrate these two paths into a cohesive product design process?* *3. Among all of the stakeholders (i.e., engineers and designers, corporate Coordinators, corporate share-holders, end-users or customers/clients), whose benefits should take precedence over other parties'? Argue your points from the perspectives of both short-term and long-terms corporate benefits.* *4. How should the efforts of individual specialists (designers, engineers, etc) be coordinated in the design team work?*

D-II-A. Possible and Acceptable Sources of Evidence of Student Learning

<u>Performance Task</u>

The Performance Task is based on the above three Teacher-generated Essential Questions and four learner-generated Essential Questions. Assignment:

1. <u>Understanding of knowledge content</u>:

   <u>Concept Maps on Industrial Product Design</u>: Each student will select one of the above three questions. Over the course of the Mini Lesson D, students will draw a few concept maps to illustrate his/her understanding of one of the above questions, with (1) sketches; and (2) graphs in either Microsoft Word or PowerPoint.

2. Application of Knowledge content:

   Design Presentation: During this Mini Lesson, groups of three students will incorporate principles of ergonomics and user safety into their design, on separate parts of the whole multi-functional food cooking device. In the Design Presentation (PowerPoint, 15 slides maximum), students will dedicate at least one slide to explain how knowledge contents from the Industrial Product Design Mini Lesson are applied in the final design. Include handout(s) if needed. Handout(s) can be student writing, or printed copies of relevant web pages or of books (do respect the "fair use" provision of copyright laws, i.e., non-profit educational use with only enough copies for the classmates, and only a few pages from each chapter).

   Student Collaboration**:** Same as in Mini Lesson B.

Upon completion of the assignment, each student will email it to the instructor and other students for information sharing and peer review/critique.

D-II-B. Possible and Acceptable Media and Materials

Instructional Materials	The following instructional materials will be used: • Engineering design and drafting software: Autodesk Inventor, or SolidWorks, etc.); • Presentation software: Microsoft PowerPoint. • Internet sites: From http://en.wikipedia.org/wiki/Product_design and others. Refer to Chapter 9 (pp. 179-181) for a list.

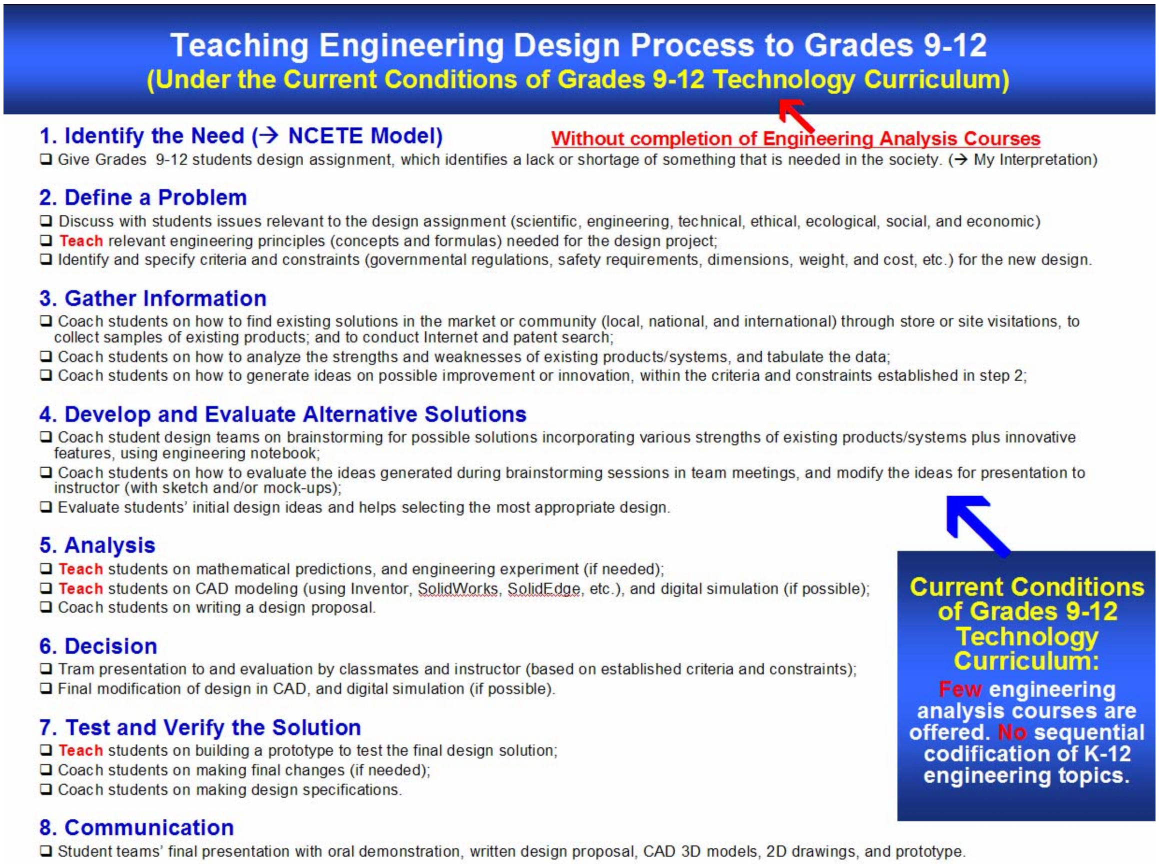


Figure 8A. NCETE High School Engineering Design Process
(with Edward Locke interpretation)

Classroom Sessions

Session 1: Review - NCETE High School Engineering Design Process

This Session can be completed in one class period.

Overview:

This Session will review the NCETE High School Engineering Design Process (*Figure 8A*), with emphasis on

1. Interdisciplinary nature of the engineering design process;
2. Integration of the linear and recursive sequences of engineering design process;
3. Importance of a thorough market research for innovative design ("Do not re-invent the wheel");

4. Importance of breaking off the "box" and of seeking better alternatives, through brainstorming activities.

Goals:

Students will, under the guidance of the instructor,

1. Review the NCETE High School Engineering Design Process, and compare what has been done in previous Mini Lessons with this Process;

2. Conduct further study of engineering design process, by Google search for "product design firm", investigate some website, study the content (pay particular attention to design samples, and statement of the firm's missions, past achievement and design process; and create a Concept Maps on Industrial Product Design in PowerPoint to illustrate what students have learned from the websites. For a list of Websites, refer to Chapter 9 (pp. 179-181).

Materials:

- PowerPoint presentation and Internet sites of product design firms;

- Handouts on Engineering Design Process (Appendix D1b).

Detailed Steps:

1. PowerPoint lecture and demonstration of relevant design firm websites.

   Lecture and presentation (20 minutes) will be followed by a Question-and-Answer period (10 minutes).

2. Under the guidance of the instructor, students will conduct Internet search on design firms.

   The instructor will provide in-class coaching and tutoring.

A Note about the lecture:

The instructor will prepare a digital list of websites of design firms worthy of additional study, and email it to students before the start of the Session.

Session 2: Product Design Related Issues (Ergonomics, Product Safety, UL Testing, Patent and Copyright Application)

This Session can be completed in one class period.

Overview:

This Session will introduce students to a variety of product design related issues, such as:

1. Ergonomics: Emphasis on the impact of product usage on human health. The following websites will be explored:
    - United States Department of Labor at http://www.osha.gov/SLTC/ergonomics/index.html;
    - Wikipedia at http://en.wikipedia.org/wiki/Ergonomics;
    - Ergonomics.org at http://ergonomics.org/.
2. Product safety: Emphasis on the inclusion of safety device in product design for the prevention of health and safety hazards (automatic shutoff valves, safety lock, fence and guides, etc.); visit the United States Product Safety Commission' website at http://www.cpsc.gov/.
3. Underwriters Laboratory (UL) testing: Endorsement from an internationally recognized product safety testing organization; visit the website at http://www.ul.com/global/eng/pages/;
4. Patent application: United State Patent and Trademark Office at http://www.uspto.gov/ will be explored.
5. Copyright application: United State Copyright Office at http://www.copyright.gov/ will be explored.

Goals:

Students will, under the guidance of the instructor, Underwriters Laboratory testing, patent and copyright applications;

- Re-study the results of the design done so far, and check the products to see if there are need and possibility for inclusion of a safety device in the Multi-functional Food Cooker.
- Conduct further study of ergonomics and product safety, by Google search for "ergonomics" and for "product safety rules, investigate some websites, study the content (pay particular attention to government rules and regulations, and to case studies; and include important information in the Concept Maps on Industrial Product Design in PowerPoint to illustrate what students have learned from the websites.

- Review and refine previous design of the Multi-functional Food Cooker, to implement principles of ergonomics and to incorporate safety devices in necessary; record the design changes in Engineering Notebook, and in Design Presentation files.

Materials:

- Computer with projector and screen;
- PowerPoint presentation and relevant websites;
- Handouts on Ergonomics, Product Safety, UL Testing, Patent and Copyright Application (Appendix D1c).

Detailed Steps:

1. PowerPoint lecture and presentation of relevant websites.

   Lecture and presentation (20 minutes) will be followed by a Question-and-Answer period (10 minutes).

2. Under the guidance of the instructor, students will conduct Internet search on relevant issues.

   The instructor will provide in-class coaching and tutoring.

A Note about the lecture:

The instructor will prepare a digital list of websites of design firms worthy of additional study, and email it to students before the start of the Session.

Sessions 3 and 4: Coaching - Computer-Aided-Design/Drafting (Additional Tools), and

Sessions 5 - 7: Completing CAD 3D Modeling and 2D Working Drawings

These Sessions can be completed in five class periods.

Overview:

These Sessions will be used to coach students with tools in CAD software (Autodesk Inventor, or SolidWorks, etc.), for the completion of digital 3D product models. Software demonstration might include:

1. General skills and frequently used tools: Graphical User Interface, Setting and Options; and tools for 3D modeling and simulation (if necessary);

2. Particularly used tools and tool combinations: For the completion of the design project.

3. 2D working drawings: Generation from 3D models and Conventions.

Goals:

Students will, under the guidance of the instructor,

- Learn or review CAD tools for 3D modeling, simulation and 2D drawing generation;
- Learn some special ways of using CAD tools;
- Review drafting conventions;
- Start CAD 3D modeling simulation (if necessary) of previous design of Multi-functional Food Cooker, with 3D part, assembly, and 2D drafting (including orthographic and isometric views, on part, assembly and explosion drawings).

Materials:

- Computer with projector and screen;
- CAD software (Autodesk Inventor, or SolidWorks, etc.);
- CAD practice files;
- Handouts on CAD Tools and Settings for the Engineering Design Challenge (Appendix D1d).

Detailed Steps:

1. Software demonstration (3 for the whole class, as listed in the Overview section).

   Software presentation at the start of Sessions 3, 4, and 5 (20 minutes) will be followed by a Question-and-Answer period (10 minutes).

2. Coaching on CAD skills.

   The instructor will coach and tutor students during classroom practice.

A Note about the lecture:

The instructor will prepare detailed handouts on step-by-step usage of CAD tools, options and settings, to help students practice them after the class meetings.

Session 8: Quiz D (Industrial Product Design)

This session is for the Mini Lesson D Quiz, a general review of the previous works, and a brief introduction to the Mini Lesson E (Manufacturing and Engineering Economics).

Overview:

The Quiz D will include 6 Multiple-Choice, 2 True and False question and 2 Fill-in problems, and will test the students on:

- Engineering design process (2 Multiple-choice);
- Ergonomics and product safety (2 Multiple-choice);
- Patent and copyright (2 Multiple-choice);
- UL testing (2 True and False);
- CAD tools and settings (2 Fill-in problems).

Goals:

Students will,

- Take Quiz D (15 minutes at the start of the Session).
- Raise additional questions during the after-test review.

Materials:

- Quiz D form;
- White board and markers.

Detailed Steps:

1. Quiz D (15 minutes);
2. Review/critique for student works during Mini Lesson D (20 minutes);

3. Question-and Answer Session (10 minutes);

4. Brief introduction to Mini Lesson E (Manufacturing and Engineering Economics).

A Note about the lecture:

Give student praise for their patience, efforts, and accomplishment so far. Encouraging students to improve learning process (be specific and courteous in explaining the shortcomings observed and new expectations for changes).

Mini Lesson E.

Manufacturing and Engineering Economics

Content/Topic Area(s)	Manufacturing and Engineering Economics
Time Frame	Weeks 14 and 15 (2 weeks total).
Description of the Learning	Students will be introduced to the basic knowledge related to the following topics: • Secondary manufacturing Process: Focus on manufacturing process of components made of metal (stainless steel, aluminum, copper), thermosetting plastics, and ceramics; and good design practice that simplify manufacturing process. • Developing Marketing Plans: Focus on product cost calculation. o (Break-Even Chart); o Maintaining Financial Records.

Learning Results for opportunities for Extension (Additional Mini Lessons)

Content Area(s)	Manufacturing and Engineering Economics.
Standard Label(s)	*Standards E. Manufacturing and Engineering Economics*
Standard(s) & Descriptor(s)	**Students will understand the economics of product design.** *Products should be designed in such a way that it will use the most effective manufacturing process and be as affordable as possible.*
Performance Indicator(s)	*Students should learn* *1. How products are manufactured.* *2. How to design products such that they can be manufactured the most economically.* *3. How to locate component manufacturers.*

Desired Results: Content and Performance Standards

E-I-A. What key *knowledge* and *skills* will learners acquire as a result of this unit?

Learners will know: (Content Standards)	*Cost effectiveness, profitability, affordability, long-term ecological sustainability, all work together in the creation of a good and well-balanced design solution.*
Learners will be	Performance Standards for Mini Lesson E (Manufacturing and

able to: (Performance Standards)	Engineering Economics) *Students should demonstrate their ability to* *1.* Correctly use the Break-Even Chart: Available online at http://connection.cwru.edu/mbac424/breakeven/BreakEven.html. See Appendix E1d for a sample. *2.* For B.S. in K-12 Engineering and Technology Teacher Education Senior-Year students Only for extra credit): *Make a working prototype with CNC equipments.*

E-I-B. What *enduring understandings* are desired?

Students will understand that:	*Cost effectiveness has several dimensions (manufacturing cost per se, impact on long-term sustainability, maintenance).*

E-I-C. What *essential questions* will guide these units (Mini Lessons) and focus teaching and learning?

Teacher-generated essential questions:	*1. What is the general trend of the historical development of manufacturing process?* *2. What is the impact of changes in manufacturing technology on economics, on human life, the changes of socio-economic systems, and on ecology?* *3. How can manufacturing technology affect the role of the nations in the age of Globalization?* *4. How to balance economics with fairness and ecology?*
Learner-generated Essential questions:	*1. What are the different categories of manufacturing and fabrication in terms of quantity?* *2. What is the common characteristics and differences among manufacturing, fabrication and construction?* *3. What are the major characteristics of the modern manufacturing process?* *4. What are the major benefits of robotics and automation?*

E-II-A. Possible and Acceptable Sources of Evidence of Student Learning

Performance Task

The Performance Task is based on the above four Teacher-generated Essential Questions and four learner--generated Essential Questions. Each student will select one of the above three questions. Assignment:

1. Understanding of knowledge content:

- Concept Maps on Manufacturing and Engineering Economics: Each student will draw a few concept maps to illustrate his/her understanding of one of the above questions, with (1) sketches; and (2) graphs in either Microsoft Word or PowerPoint; or

2. Application of Knowledge content:

   Design Presentation: During this Mini Lesson, al students in the class will conduct a full class meeting to (1) discuss the design of all components so far; (2) decide on any needed changes to be made on any component, based on knowledge on modern manufacturing process and principles of economics; and (3) assign students to carry out the changes and prepare for the final digital 3D models and 2D working drawings, ready to final prototyping and presentation.

   In the Final Design Presentation (PowerPoint, 15 slides maximum), students will dedicate at least one slide to explain how knowledge contents from the Manufacturing and Engineering Economics Mini Lesson are applied in the final design. Include handout(s) if needed. Handout(s) can be printed copies of relevant web pages or of books (do respect the "fair use" provision of copyright laws, i.e., non-profit educational use with only enough copies for the classmates, and only a few pages from each chapter).

   Student Collaboration**:** Whole class working together.

Upon completion of the assignment, each student will email it to the instructor and other students for information sharing and peer review/critique.

E-II-B. Possible and Acceptable Media and Materials

Instructional Materials	The following instructional materials will be used: • Internet source: Such as http://en.wikipedia.org/wiki/Manufacturing (See Chapter 9, pp. 181-184 for a list). • PowerPoint presentation. • Demonstration: Tools, samples of products, etc. • Video: From http://www.youtube.com (See Chapter 9, pp. 181-184 for a list)

Classroom Sessions

Sessions 1 and 2: Secondary Manufacturing Process and Good Design Practice (Lecture/Internet Video/Sample Display/Coaching)

These Sessions can be completed in two class periods.

Overview:

These Sessions will review secondary manufacturing process and good design practice, with lecture, Internet search, video show and display of production mold samples. Topics will include:

1. Casting and molding processes;
2. Forming processes;
3. Separating processes;
4. Conditioning processes;
5. Assembling processes;
6. Finishing processes.

Goals:

Students will, under the guidance of the instructor,

1. Understand the basics of secondary production processes, the advantages and limitations of each process, and their impact on parts and assembly design; and incorporate this understanding in the Concept Maps or PowerPoint Presentation on Manufacturing and Engineering Economics
2. Assign each part in the Multi-functional Food Cooker designed during previous Engineering Design Challenge activities to a particular production process, make adjustments to the design of any part if necessary; and record the assignment and design modifications in Engineering Notebook and in the Design Presentation file.

Materials:

- Computer with projector and screen;
- PowerPoint presentation;
- Internet sites of manufacturing firms;
- Youtube and other Internet video show. Refer to Chapter 9 (pp. 181-183) for a list.
- Display of samples of manufacturing tooling (jigs, fixture, templates, etc.).

- Handouts on Manufacturing Process and Good Design Practice (Appendix E1b).

Detailed Steps:

1. PowerPoint lecture, display of relevant production tooling, and short video show.

   Lecture and presentation (30 minutes) will be followed by a Question-and-Answer period (10 minutes). Students will watch additional videos using instructor-provided website links after class.

2. Under the guidance of the instructor, students will

   - Review and modified previous design in 3D CAD models; and
   - Generate 2D working drawings (including orthographic views, isometric and explosion);
   - Record the final changes made to the design of Multi-functional Food Cooker in Engineering Notebook, and in Design Presentation PowerPoint file to make it ready for Final Design Presentation and Critique.

   The instructor will provide in-class coaching and tutoring.

A Note about the lecture:

The instructor will prepare a digital list of websites of manufacturing firms and Youtube videos on manufacturing processes and email it to students before the start of the Session, for students to study before and after the Sessions. During class meeting time, the instructor will spend most of the time explaining good design practices that streamline manufacturing processes.

Sessions 3 and 4: Modern Manufacturing and CNC Prototyping (Lecture/Internet Video/Sample Display)

This Session can be completed in two class periods.

Overview:

These Sessions will introduce students to modern manufacturing and prototyping; topic will include:

1. Modern manufacturing: Robotic-based modern part manufacturing and assembly. Websites and videos to be explored might include the following:

   Websites: Refer to Chapter 9 (p. 183) for a list.

   Videos: Refer to Chapter 9 (p. 183) for a list.

2. CNC prototyping:

   - The instructor will give a pre-arranged tour of the school's or an outside-of school CNC prototyping facility, and introduce students to prototyping of the Multi-functional Food Cooker designed during the entire Engineering Design Challenge.

Goals:

Students will, under the guidance of the instructor,

- Learn the basics of robotic-based modern manufacturing.
- For student in B.S. in K-12 Engineering and Technology Education program: Students will start building the prototype for the Multi-functional Food Cooker designed during the entire Engineering Design Challenge.
- For high school students in Engineering Career Pathways: Students will conduct online research on modern manufacturing process; and continue working on CAD 3D modeling and 2D drafting, and refining Final presentation materials.

Materials:

- Computer with projector and screen;
- PowerPoint presentation, websites, and Youtube videos;
- Handouts on Modern Manufacturing and CNC Prototyping (Appendix E1c).

Detailed Steps:

1. PowerPoint lecture and short video show.

   Lecture and presentation (30 minutes) will be followed by a Question-and-Answer period (10 minutes). Students will watch additional videos using instructor-provided website links after class.

2. Visiting CNC prototyping facility (the balance of the Sessions).

   The instructor will provide a tour to available CNC prototyping facility.

<u>A Note about the lecture:</u>

The instructor will prepare a digital list of websites of manufacturing firms and Youtube videos on modern robotic-based manufacturing processes and email it to students before the start of the Session, for students to study before and after the Sessions (including those listed in the Overview section). Before the start of the Sessions, the instructor will make arrangement with the manager of available CNC prototyping facility for touring and using the equipment and materials.

Sessions 5 - 7:

<u>For B.S. in K-12 Engineering and Technology Teacher Education students</u>: CNC Prototyping (Supervised Lab Manufacturing Activity)

<u>For high school students</u>: Completing CAD Design and Drafting Activity

These Sessions can be completed in three class periods.

The prototyping activity is for B.S. in K-12 Engineering and Technology Teacher Education Senior-Year students ONLY, EXCEPT in well-equipped high school where CNC labs are available and where CNC manufacturing course have been previously taught to high school Grade 12 students enrolled in Engineering and Technology Career Pathways. For most of high school, this block of time will be used to complete writing assignments, on 3D CAD modeling and 2D drawing generation works, and on refining Final presentation materials.

<u>Overview</u>:

These Sessions will be used by students to complete their assignments and prepare for Final Design Presentation.

<u>Goals:</u>

Students will, under the guidance of the instructor,

1. <u>For B.S. in K-12 Engineering and Technology Teacher Education students</u>: Completing CAD design and drafting activity, CNC Prototyping (supervised by the instructor), and refining Final presentation materials.

2. For high school students: Completing CAD design and drafting activity, and refining Final presentation materials.

Materials:

1. Computer with projector and screen;
2. Metal, plastic and other materials (for CNC lab prototyping activity);
3. CAD software (Autodesk Inventor, or SolidWorks, etc.);
4. Handouts on Modern Manufacturing and CNC Prototyping (Appendix E1c).

Detailed Steps:

- Lab pr classroom supervision and coaching.

  The instructor will coach and supervise students during their respective activities.

A Note about the Sessions:

1. For B.S. in K-12 Engineering and Technology Teacher Education students: The instructor will closely supervise student prototyping activities, and pay close attention to students' observance of facility safety rules..
2. For high school students: The instructor will extensively coach students on completing CAD design and drafting activity, and refining Final presentation materials.

Session 8: Developing Marketing Plans (Break-Even Chart)

This Session can be completed in one class period.

Overview:

This Session will be used to introduce some principles of engineering economics to students. Topics might include:

1. Pricing products: Concepts of factory cost, labor cost, overhead, administration cost, and selling cost will be introduced (Wright, 2004, p. 362);

2. Financial records: Types of budgets (sales, production expense, general expense, financial and master), and general accounting (balance sheet, income statement, cost accounting) will be introduced (Wright, 2004, pp. 392-397);

3. Break-Even Chart: Information from http://connection.cwru.edu/mbac424/breakeven/BreakEven.html and other websites will be used to cover this topic).

Goals:

Students will

- Learn the basics of engineering economics;

- Learn to calculate the Break-Even Point using both formula and online digital calculator (at http://connection.cwru.edu/mbac424/breakeven/BreakEven.html), by a classroom exercise.

Materials:

- Computer with projector and screen;

- Internet search engine;

2. Break-Even Chart Information and Sample Calculation (Appendix E1d).

Detailed Steps:

1. Lecture and online calculator demonstration.

   Lecture and demonstration (20 minutes) will be followed by a Question-and-Answer period (10 minutes).

2. In class Break-Even Point exercise.

   The instructor will coach and tutor students during classroom practice.

A Note about the lecture:

The instructor will prepare detailed handouts on step-by-step usage of Break-Even Point formula and online calculator, to help students practice them after the class meetings.

Beyond the Mini Lessons (2 Weeks): Time to Complete the Project

Classroom Sessions

Session 1: Quiz E (Manufacturing and Engineering Economics)

This session is for the Mini Lesson E Quiz, a general review of the previous works, and a brief introduction to the Mini Lesson E (Manufacturing and Engineering Economics).

Overview:

The Quiz E will include 2 Multiple-Choice, 2 True and False question, 2 Fill-in problems, and 2 worked-out problems, and will test the students on:

- Pricing products (2 Multiple-choice);
- Financial records (types of budgets) (2 True and False);
- Financial records (general accounting) (2 Fill-in problems);
- Break-Even Point (2 worked-out problems).

Goals:

Students will,

- Take Quiz E (30 minutes at the start of the Session).
- Raise additional questions during the after-test review.

Materials:

- Quiz E form;
- White board and markers.

Detailed Steps:

5. Quiz E (30 minutes);
6. General review/critique for student works during the entire course (30 minutes);

7. Question-and Answer Session (10 minutes);

A Note about the lecture:

Give student praise for their patience, efforts, and accomplishment so far. Encouraging students to improve learning process (be specific and courteous in explaining the shortcomings observed and new expectations for the Finals).

Session 2: PowerPoint and Concept Maps presentations

This session is designed as a general review of all Mini Lesson topics covered in the entire course. Individual students to give various presentations to the whole class; students will raise questions and the instructor will offer critique. The instructor will give a final review on the most important topics covered in all Mini Lessons. Individual student will spend 10-15 minutes per presentation. If additional time is needed, then the subsequent Sessions can be used.

Overview:

Student presentations will include:

- PowerPoint presentation on Material Selection Mini Lesson;
- Collection of Design Aesthetics Samples
- Concept Maps on Industrial Product Design;
- PowerPoint Presentation on Manufacturing and Engineering Economics.

Goals:

Individual students will,

- Present their findings related to Mini Lessons;
- Answer questions by other students;
- Hear critique and comments from the instructor and other students.

The instructor will give an overall review for the entire course.

Materials:

- Computer with projector and screen;

- White board and markers.

Detailed Steps:

1. Individual student presentation (10-15 minutes each);
2. General review/critique for the entire course by the instructor (30 minutes);
3. Question-and Answer Session (20 minutes);

A Note about the lecture:

Give student praise for their patience, efforts, and accomplishment so far. Encouraging students to improve learning process (be specific and courteous in explaining the shortcomings observed and new expectations for the Finals).

Sessions 3 and 4:

For B.S. in K-12 Engineering and Technology Teacher Education students: Completing CNC Prototyping Activity

For high school students: Completing CAD Design and Drafting Activity

These sessions are for students to complete their project and prepare for the Final Design Presentation and Critique (Sessions 9 - 12).

Overview:

The instructor will help students to complete their project with additional coaching on project related skills.

For B.S. in K-12 Engineering and Technology Teacher Education senior-year students:

- Prototyping equipment usage.

For high school Grade 12 Engineering and Technology Career Pathway students:

- CAD 3D modeling and 2D drawing generation tools.

Goals:

- Completion of the Engineering Design Challenge.

Materials:

For B.S. in K-12 Engineering and Technology Teacher Education students:

- Prototyping facility.

For high school Grade 12 Engineering and Technology Career Pathway students:

- CAD classroom.

Detailed Steps:

The instructor will help students completing their projects.

A Note about the lecture:

The instructor will work as an assistant to students.

Sessions 9 - 12: Final Design Presentation and Critique and Submission of Engineering Design Challenge Portfolio

These sessions are for the Student Groups to offer their respective parts of the Final Design Presentation to the entire class, to hear critique and comments from the instructor and other students; and to submit their parts of the Engineering Design Challenge Portfolio, with CAD drawings, prototype (for B.S. in K-12 Engineering and Technology Teacher Education senior-year students ONLY), hard copies of Reports related to Engineering design Challenge activities, Concept Maps, PowerPoint Presentations, Logo or Packaging Design, Reflection Papers, and Collection of Design Aesthetics Samples.

Overview:

Student Group presentation will include the following parts of the Engineering Design Challenge:

- Existing Products;
- Heat Transfer Computations;
- Potentiometer Design and Testing;
- Design of New Food Cooking Electro-Thermal Interface and Food Containers;

- Material Selection and Suppliers ;
- Logo or Packaging Design;
- Incorporation of Principles of Ergonomics and User Safety;
- CAD 3D Modeling and 2D Working Drawings;
- Demonstration of the prototype (for B.S. in K-12 Engineering and Technology Teacher Education senior-year students ONLY).

Goals:

Students will,

- Give a professional presentation on their completed design;
- Offer and listen to critique and comments by the instructor and other students;
- Ask and answer questions during the presentations;
- Ask any additional questions to the instructor;
- Fill out a course evaluation form and bring it to the Administration.

The instructor will give final comments on the course and answer students' questions.

Materials:

- Computer with projector and screen;
- White board and markers.

Detailed Steps:

- Student Group presentation (20-30 minutes per group);
- Critique, comment, Question-and-Answer (10-20 minutes per group);
- The instructor's final critique and comments (10-20 minutes for the entire class);
- The instructor's final Question-and Answer Session (10-20 minutes).

A Note about the lecture:

Give student praise for their patience, efforts, and accomplishment so far. Encouraging students to improve learning process (be specific and courteous in explaining the shortcomings observed and new expectations for future career).

A General Template for Additional Engineering Design Challenges

Additional Engineering Design Challenges can be developed using this one as a general template. In this case, Mini Lesson A will need substantial changes, while Mini Lesson B through E will need either no changes or minor changes in particular pieces of knowledge content.

Engineering Challenge Curriculum Project
NCETE Core 4, Spring 2009, UGA
Professor: Dr. Kurt Becker
Student: Edward Locke (elocke@uga.edu)

Additional Engineering Design Challenge: A Multi-functional Food Processor

Changes in Mini Lesson A:

About 50% change. Same transition from "Analytic Reduction" Model to "System Thinking" Model of Engineering Design Process (*Figure 8B*).

Mini Lesson A (6 Weeks): **Physics for Scientists and Engineers (Electricity and Mechanism)**				
Wk	**Hr ***	**Mini Lesson Topic**	**Assignment (Due Week → Credit)**	**Reading**
1	1	Introduction to (1) Engineering Design Challenge, and (2) NCETE High School Engineering Design Process	Group and Company Report on Existing Food Processing Appliances (Due: Week 4 → 5 Points)	Serway & Jewett** Ch. 27, 28 or Crawford et al*** Ch/Sec. 1.3, 2.3, 3.3, 4.3, 5.3 and 6.3 + Wentzell **** Ch. 1, 2, 6, 8, 9, 11-21
	2	Market Research		
	3	Ohm's Law and Circuit Analysis		
	4	Reverse Engineering		
2	1	Potentiometer Design (computation)		
	2	Potentiometer Design (Simulation with ElectronicsWorkbench)		
	3	Potentiometer Design (Breadboard Testing)		
	4	Potentiometer Design (Report Writing)		
3	1	Mechanical Devices	Group and Company Report on Mechanical Devices (Due: Week 5 → 5 Points)	Serway & Jewett** Ch. 19-22, or Crawford et al*** Ch/Sec. 1.4, 3.4, 4.4, 5.4 + Wentzell **** Ch. 1, 2, 6, 8, 9, 11-21
	2	Electrical Motors (Analytic Computations and Predictions)		
	3			
	4			
4	1	Design, Fabrication and Testing of A Multiple-Speed Electrical Motor	Group and Company Report on Electrical Motors Design and Testing (Due: Week 6 → 5 Points)	
	2			
	3			
	4			
5	1	Design of Food Processing Attachments (Processing Devices and Containers) (Supervised Student Activity)	Group and Company Report on Design of New Food Processing Blades and Containers (Due: Week 8 → 5 Points)	
	2			
	3			
	4			
6	1			
	2			
	3			
	4	Quiz A (Electricity and Mechanical Devices) →5 Points		

Note:

* **For high school Grade 12 students in Engineering and Technology Career Pathways:** Basically, this unit (Mini Lesson) will be taught in a block schedule in which classes meet for approximately 90 minutes, 4 days per week. Each lecture will last 15-30 minutes; and this will leave 60-45 minutes for student works in the classroom.

For B.S. in K-12 Engineering and Technology Teacher Education Senior-Year students: Basically, this Mini Lesson will be the 1st part of a 4-credit unit Senior-Year Design course, meeting 2 days a week (3 hours each). Each lecture will last 15-30 minutes; and the balance of classroom meeting time is reserved for student works.

Lecture is usually based on PowerPoint presentation and can include demonstration of artifacts or skills and Internet video shows. Each lecture will be followed by a corresponding student activity.

** For high school Grade 12 students.

*** For B.S. in K-12 Engineering and Technology Teacher Education students.

**** Wentzell, T. H. (2004). *Machine Design*. USA: Thompson Delmar Learning. ISBN No. 140180517-5 (*Figure 8C*).

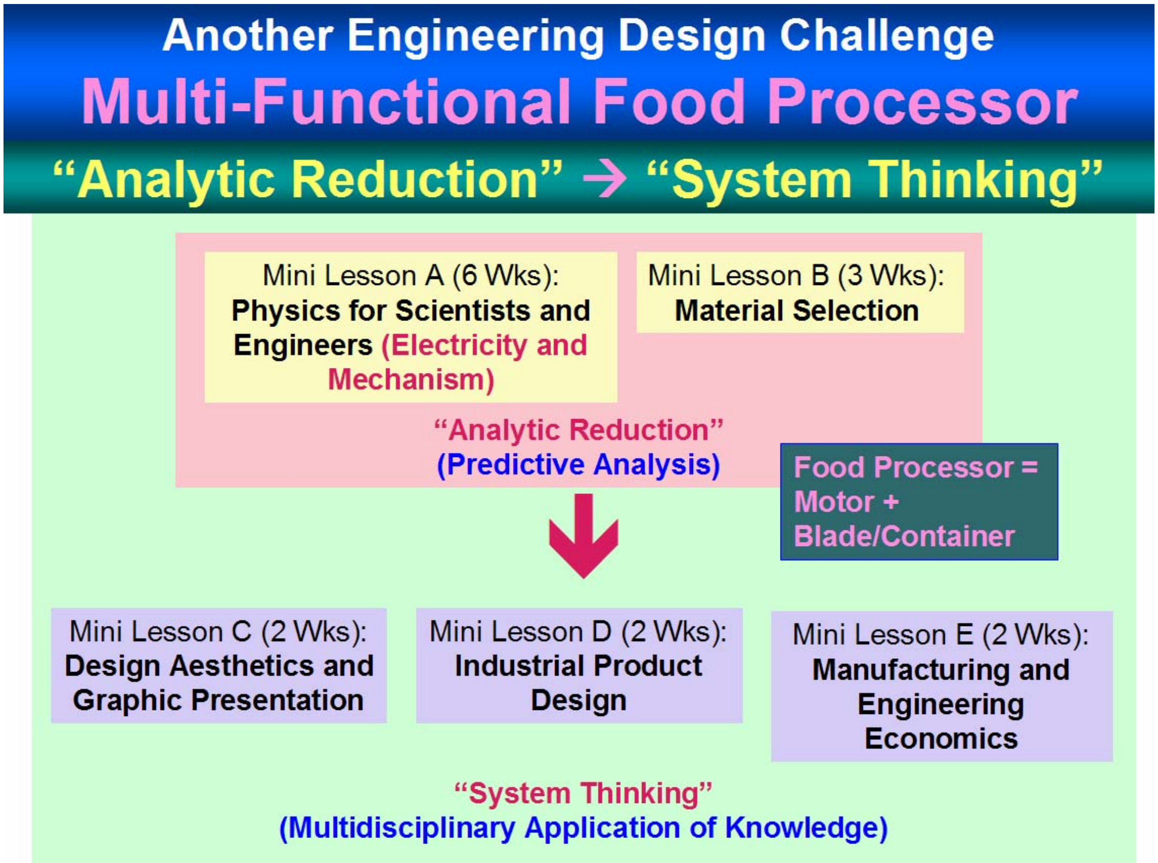


Figure 8B. Same transition from "Analytic Reduction" Model to "System Thinking" Model of Engineering Design Process, in the new Engineering Design Challenge (Multi-functional Food Processor).

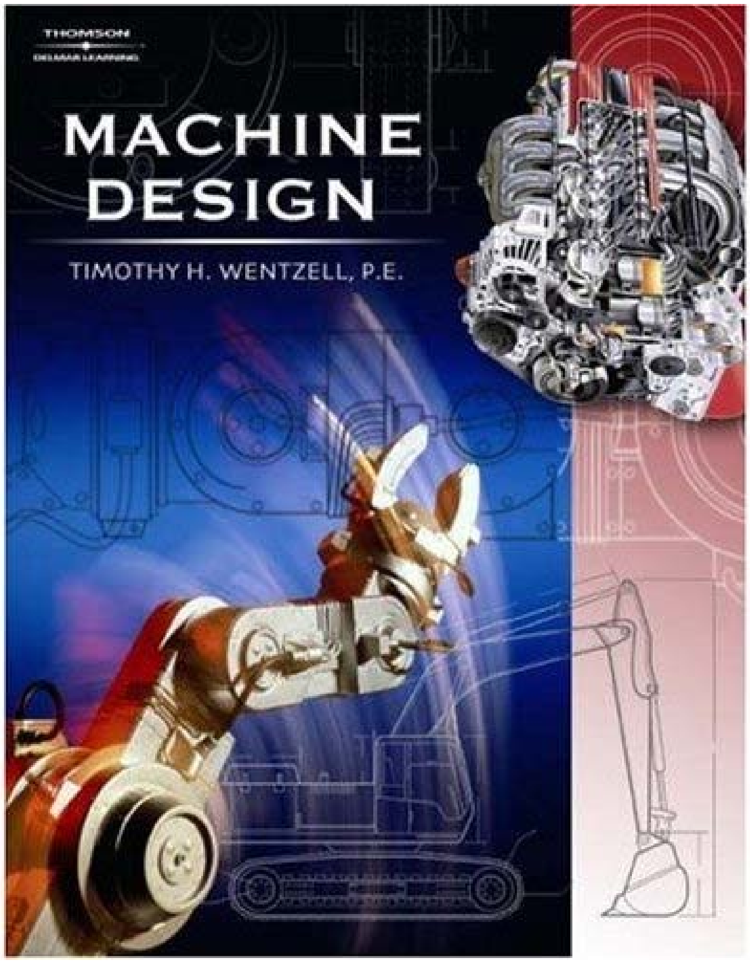


Figure 8C. Machine Design textbook.

Changes in Mini Lesson B:

Practically none, except that the types of materials now include (1) metals (as usual); (2) plastics (as usual); and (3) glass (instead of ceramics)

Changes in Mini Lessons C - E:

None.

Chapter 9: Instructor Resources

Chapter 1 (pp. 17-20) list the main textbooks for students and main reference books for the instructors' development of instructional materials.

This Chapter will list additional resources for the instructors to explore and use as reference for the creation of PowerPoint presentation files, and for classroom demonstration. The list will also be made available to students as learning materials (through Internet search, watching instructional videos, and online calculator practice).

Internet Sources (Websites, Videos, online Calculators) for the Mini Lessons

Mini Lesson A (Physics for Scientists and Engineers - Circuit Analysis and Heat Transfer)

Session 3: Ohm's Law and Circuit Analysis, and

Sessions 5 - 7: Potentiometer Design

- Websites: Circuit analysis and potentiometer.
    - Potentiometer at http://en.wikipedia.org/wiki/Potentiometer
    - Potentiometer as a voltage divider at http://www.allaboutcircuits.com/vol_6/chpt_3/6.html
    - Potentiometer as a rheostat at http://www.allaboutcircuits.com/vol_6/chpt_3/7.html
    - What is a Potentiometer at http://www.wisegeek.com/what-is-a-potentiometer.htm
    - Ohm's law at http://en.wikipedia.org/wiki/Ohm's_law
    - Electric Circuit Analysis at http://en.wikiversity.org/wiki/Electric_Circuit_Analysis
    - Basic electrical laws & circuits theory at http://www.circuit-magic.com/laws.htm
    - NASA Education Heat Transfer lesson at http://www.grc.nasa.gov/WWW/K-12/airplane/heat.html

For additional articles on related topics from NASA Education sites:

- "electrical circuit analysis:"
  - http://search.nasa.gov/search/search?q=%22electrical+circuit+analysis%22&btnG.x=16&btnG.y=15&btnG=GO&cx=015120938291988892029%3Aka38_jv-tpy&client=google-csbe&output=xml_no_dtd&adkw=AELymgXdM18jSY1WSYTZan3wPrqrlgaqH8DS0sMun37DkD76Yo7P44KjyrKTm66nR2kkZNivw5DEUqcMBz5Q67aM3G1g_LXiNUWcnPAI19-PsokwUn9hxgxhg9O__2-pTqFnjHkcy6dDTNBtoTEG-BuRXBLHdL8pJu2HAFvXamAxuWMBATMmGDN75McSqsITbk3lr_ioqnD1CeyNCCaYvwuCt3e8fU7Njg&hl=en&oe=UTF-8&ie=UTF-8&boostcse=0
- "potentiometer:"
  - http://search.nasa.gov/search/search?q=%22potentiometer%22&btnG.x=0&btnG.y=0&btnG=GO&cx=015120938291988892029%3Aka38_jv-tpy&client=google-csbe&output=xml_no_dtd&ie=UTF-8&oe=UTF-8&adkw=AELymgUjCK7ekQLHLz2sCJVQntS4RMfvkt0LNJfd4SXgHCeDS6UfCME3E321OEH712tJvy-YbpMDUC5BF3ZJBwuu78PTbQZyRD0wqjGIlZs9EJJsHEvR5CklYEckxtwIRQ1Za-JpyEUL92a2vJXzvQTDceUYfMAg057O8v5V3uAOVE6Nrh1UqR6wKO5rTlwLnoqlbWW-Sb0E4-G16RaQPc9QKpkDdQrI_Q&hl=en&boostcse=0
- "heat transfer"
  - http://search.nasa.gov/search/search?q=%22heat+transfer%22&btnG.x=16&btnG.y=17&btnG=GO&cx=015120938291988892029%3Aka38_jv-tpy&client=google-csbe&output=xml_no_dtd&ie=UTF-8&oe=UTF-8&adkw=AELymgVg0Wd6VzltLpdHNASvFPA8juJQ0gJ9q8Jiwgkq0cq8_A6f1td7GmVHEeJ7tcpUG-6NnLv7robVWH1jiZ5Bumze3nHaa2JyzI8k4u-P0BQXHNDycAmAjAVnVE9PuuhySI1ROWSc5ujfuuDk4nnWhYaqXyH5xhQZONCOruK-LAbx0E4VP_ATytyWi10WgWsy9O1mYPDtFefWMiTs0TNcSKLUJ9QojQ&hl=en&boostcse=0

- YouTube videos: Circuit analysis and potentiometer.

- Introduction to Circuit Analysis - Water Analogy at http://www.youtube.com/watch?v=j8TyygWl9nQ&feature=related
- Electric Circuit Analysis - Circuit Variables: Current, Voltage, Power at http://www.youtube.com/watch?v=lbRiLEU_JIA
- How to Build Electronic Circuits : How to Measure Current in a Circuit at http://www.youtube.com/watch?v=0FXpFAFv3Cw&feature=related
- Electricity 10 Potentiometer and potential divider at http://www.youtube.com/watch?v=OIV8b0qEZ1M
- Potentiometer (overview) at http://www.youtube.com/watch?v=GZMe-xohlrs&feature=related
- Potentiometer at http://www.youtube.com/watch?v=U0lZPj2nObg&feature=related

Sessions 9 - 12: Heat Transfer

- Websites: Heat transfer and thermodynamics.
  - Heat transfer at http://en.wikipedia.org/wiki/Heat_transfer
  - Heat Transfer (Conduction Convection Radiation) at http://sol.sci.uop.edu/~jfalward/heattransfer/heattransfer.html
  - Heat Transfer: Conduction, Convection, Radiation - Learning Activity at http://www.wisc-online.com/objects/index_tj.asp?objID=SCE304
  - Thermodynamics at http://en.wikipedia.org/wiki/Thermodynamics
  - http://www.grc.nasa.gov/WWW/K-12/airplane/heat.html
  - Zeroth law of thermodynamics at http://en.wikipedia.org/wiki/Zeroth_law_of_thermodynamics
  - Thermodynamic Equilibrium at http://www.grc.nasa.gov/WWW/K-12/airplane/thermo0.html
  - Thermal Equilibrium at http://hyperphysics.phy-astr.gsu.edu/Hbase/thermo/thereq.html
  - Temperature Measurement at http://en.wikipedia.org/wiki/Temperature_measurement
  - Temperature Scale at http://www.thefreedictionary.com/temperature+scale

  - First Law of Thermodynamics at http://en.wikipedia.org/wiki/First_law_of_thermodynamics
  - First Law of Thermodynamics at http://hyperphysics.phy-astr.gsu.edu/HBASE/thermo/firlaw.html
  - Second Law of Thermal Dynamics at http://en.wikipedia.org/wiki/Second_law_of_thermodynamics
  - Second Law of Thermal Dynamics at http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/seclaw.html
  - Calorimetry at http://en.wikipedia.org/wiki/Calorimetry
  - Calorimetry at http://hyperphysics.phy-astr.gsu.edu/Hbase/thermo/calor.html
  - Heat Flow Rate Converter at http://www.1728.com/convheat.htm
  - Heat at http://en.wikipedia.org/wiki/Heat

- YouTube videos: Heat transfer and thermodynamics.
  - Physics: Heat Transfer at http://www.youtube.com/watch?v=0rW9urrlS-I
  - Heat Transfer For Dummies at http://www.youtube.com/watch?v=zklNV9ynCTw
  - Convection, Conduction, and Radiation at http://www.youtube.com/watch?v=VzE_IPedujc&feature=related
  - Thermodynamics and Heat Transfer at http://www.youtube.com/watch?v=n4GKe4VYFGk&feature=related
  - Physics: Second Law of Thermodynamics at http://www.youtube.com/watch?v=0vIuYukyAUQ
  - Physics 2 - Sample 2 - First Law of Thermodynamics at http://www.youtube.com/watch?v=FAICvfbqNKs
  - Calorimetry at http://www.youtube.com/watch?v=hrnYuI9Wbq0

Mini Lesson B (Material Selection)

Sessions 1 and 2: Material Properties and Applications

- Websites: Engineering materials.
  - Metal at http://en.wikipedia.org/wiki/Metal
  - A Short History of Metals at http://neon.mems.cmu.edu/cramb/Processing/history.html
  - Alloy at http://en.wikipedia.org/wiki/Alloy
  - Stainless steel at http://en.wikipedia.org/wiki/Stainless_steel
  - Plastic at http://en.wikipedia.org/wiki/Plastic
  - Ceramic at http://en.wikipedia.org/wiki/Ceramic
  - Glass at http://en.wikipedia.org/wiki/Glass
- YouTube videos: Engineering materials.
  - Aluminum Foil in The Microwave at http://www.youtube.com/watch?v=EFLUeH38ITM
  - Making Aluminum Foil at http://www.youtube.com/watch?v=4W4Ca7x7Z7s&feature=related
  - HowItsMade_AluminumCans at http://www.youtube.com/watch?v=SJNwsZH53-A&feature=related
  - Stainless Steel Bottles at http://www.youtube.com/watch?v=b43B8B3307w
  - Why Is Plastic Packaging Toxic at http://www.youtube.com/watch?v=BvzTr1VOK90&feature=related
  - The Dangers of Plastic Bags http://www.youtube.com/watch?v=lhxX1g9A2OM&feature=related
  - How to cut Plastic Sheet at http://www.youtube.com/watch?v=nh62xaTEmxw
  - Is Plastic the Problem, or Recycling? - Lynda Resnick at http://www.youtube.com/watch?v=DQctEpHNlqc

- Elements of Tempering, Normalizing, and Annealing at http://www.youtube.com/watch?v=COasmrnxbqg&feature=related
- Materials Science and Engineering at Penn State at http://www.youtube.com/watch?v=hVwBTWYwwsg
- The future of materials: Advanced Ceramics at http://www.youtube.com/watch?v=69Y0VuOYqkU&feature=related
- Basic Atomic Structure at http://www.youtube.com/watch?v=Gsf7jhWr6ng
- Periodic Properties of the Elements at http://www.youtube.com/watch?v=AkoepZtvaXg&feature=related
- Composite Materials at http://www.youtube.com/watch?v=Eq6Xj1UcIKg&feature=channel
- Understanding Plastic Materials - Definition of Plastics (excerpt) at http://www.youtube.com/watch?v=N2GORjS9q5U
- Ductility of metals at http://www.youtube.com/watch?v=OkuDM3hYutI&feature=related
- Magnetic Metals at http://www.youtube.com/watch?v=VkS3EiYRo4E
- Properties of alloys at http://www.youtube.com/watch?v=Fs0ikw1TEmY

Mini Lesson C (Design Aesthetics and Graphic Presentation)

Session 1: Elements of Aesthetics (Points, Lines, Surfaces, 2D Shapes, 3D Bodies, Colors) and Product Exterior Design

- Websites: Two- and three-dimensional arts and design.
  - Two-Dimensional Art at http://wps.prenhall.com/wps/media/objects/259/265596/getstart/two_d.html
  - Introduction to Art/The Basics of Two-Dimensional Art at
  - http://en.wikibooks.org/wiki/Introduction_to_Art/The_Basics_of_Two-Dimensional_Art
  - Color at http://en.wikipedia.org/wiki/Color

- Figures and polygons at http://www.mathleague.com/help/geometry/polygons.htm
- http://en.wikipedia.org/wiki/Area at http://en.wikipedia.org/wiki/Area
- Volume at http://en.wikipedia.org/wiki/Volume
- Volume Formulas at http://www.math.com/tables/geometry/volumes.htm
- Line (geometry) at http://en.wikipedia.org/wiki/Straight_line
- Point (geometry)at http://en.wikipedia.org/wiki/Point_(geometry)
- WARPED SURFACE at http://www.websters-online-dictionary.org/Wa/Warped+surface.html
- Cartesian coordinate system at http://en.wikipedia.org/wiki/Cartesian_coordinate
- CSG Volume Calculator at http://www.csgnetwork.com/volumecalc.html
- Water/Wastewater Math Calculator
  Tank Volume Calculator at http://www.dep.state.pa.us/dep/deputate/waterops/redesign/calculators/volcalchtm.htm
- ABE Volume Calculator Page at http://grapevine.abe.msstate.edu/~fto/tools/vol/index.html
- CSG Area Calculator at http://www.csgnetwork.com/areacalc.html
- CSG Irregular Polygon Area Calculator at http://www.csgnetwork.com/areairregpolycalc.html
- CSG Surface Area Calculator at http://www.csgnetwork.com/surfareacalc.html
- Ellipse Area Calculator at http://www.csgnetwork.com/areaellipse.html
- Parallelogram Area Calculator at http://www.csgnetwork.com/areaparallel.html
- Pyramid Surface Area Calculator at http://www.csgnetwork.com/areapyramid.html
- Trapezoid Area Calculator at http://www.csgnetwork.com/areatrapezoid.html

- Square (geometry) at http://en.wikipedia.org/wiki/Square_(geometry)
- Cube at http://en.wikipedia.org/wiki/Cube
- Trapezohedron at http://en.wikipedia.org/wiki/Trapezohedron
- Rhombic triacontahedron at http://en.wikipedia.org/wiki/Rhombic_triacontahedron
- Quasiregular rhombic tiling at http://en.wikipedia.org/wiki/Quasiregular_rhombic_tiling
- Tiling by regular polygons at http://en.wikipedia.org/wiki/Tilings_of_regular_polygons
- List of uniform tilings at http://en.wikipedia.org/wiki/List_of_uniform_tilings
- Wythoff symbol at http://en.wikipedia.org/wiki/Wythoff_symbol
- Regular polyhedron at http://en.wikipedia.org/wiki/Regular_polyhedron
- Uniform polyhedron at http://en.wikipedia.org/wiki/Uniform_polyhedron
- Rhombic dodecahedron at http://en.wikipedia.org/wiki/Rhombic_dodecahedron
- Circle at http://en.wikipedia.org/wiki/Circle
- Triangle at http://en.wikipedia.org/wiki/Triangle
- Animated demonstrations of triangle constructions using compass and straightedge at http://www.mathopenref.com/tocs/constructionstoc.html
- Triangulation at http://en.wikipedia.org/wiki/Triangulation
- Ellipse at http://en.wikipedia.org/wiki/Ellipse
- Ellipsoid at http://en.wikipedia.org/wiki/Ellipsoid
- Paraboloid at http://en.wikipedia.org/wiki/Paraboloid
- Hyperboloid at http://en.wikipedia.org/wiki/Hyperboloid
- Hyperboloid structure at http://en.wikipedia.org/wiki/Hyperboloid_structure
- Ruled surface at http://en.wikipedia.org/wiki/Ruled_surface

  - Hyperbola at http://en.wikipedia.org/wiki/Hyperbola
  - Quadric at http://en.wikipedia.org/wiki/Quadric
  - Cone (geometry) at http://en.wikipedia.org/wiki/Cone_(geometry)
  - Pyramid at http://en.wikipedia.org/wiki/Pyramid

- <u>YouTube videos</u>: Two- and three-dimensional arts and design.
  - Basic Two-Dimensional Design : Radial Balance in Two-Dimensional Design at http://www.youtube.com/watch?v=5MGoJzwHnzY
  - Basic Two-Dimensional Design : Two-Dimensional Design Field Sizes at http://www.youtube.com/watch?v=jxE1BMwwTDQ&feature=channel
  - Basic Two-Dimensional Design : Symmetry in Two-Dimensional Design at http://www.youtube.com/watch?v=zICJs8Xm3CU&feature=channel
  - Basic Two-Dimensional Design : Radial Balance in Two-Dimensional Design at http://www.youtube.com/watch?v=5MGoJzwHnzY&feature=channel
  - Conceptual Interactive - Three Dimensional Designs – Demo at http://www.youtube.com/watch?v=emhXwYEi2Q8
  - Dimensional Art at http://www.youtube.com/watch?v=ieCBIJPwks4
  - 3D art at http://www.youtube.com/watch?v=1160pdigVIc&feature=related
  - What colors do you like at http://www.youtube.com/watch?v=GzGvV7OAXvY&feature=channel
  - Lots of Shapes - Children's video at http://www.youtube.com/watch?v=Jb9Zn8dzL1k&feature=channel
  - Opposites at http://www.youtube.com/watch?v=_cg80uObQRc&feature=channel
  - African Art at http://www.youtube.com/watch?v=TZdGIl39pwM&feature=related
  - National Museum of African Art at http://www.youtube.com/watch?v=3PmpteYniB8&feature=related
  - African art discussion with African Encounters at http://www.youtube.com/watch?v=znf6W0fbPLg

- Scandinavian glass design by Scandinavian Interior, Finland at http://www.youtube.com/watch?v=OgchpB0AHTA&feature=related
- SWEDISH ART at http://www.youtube.com/watch?v=tVVn1YDR-tE
- Ikea commercial – Home at http://www.youtube.com/watch?v=XJBOjiTVh4w
- Oriental Art at http://www.youtube.com/watch?v=qShuse6dR6Q
- Chinese Painting and Calligraphy in 3D at http://www.youtube.com/watch?v=imxXfC0Isk0&feature=related
- Celtic Art Games & Tables at http://www.youtube.com/watch?v=a5FKm29fxyY&feature=PlayList&p=4D0C6A3C5E2FCE8B&index=0
- Celtic Art at http://www.youtube.com/watch?v=pQnswF3LBTQ&feature=related
- Imperial Hotel Lobby, Frank Lloyd Wright at http://www.youtube.com/watch?v=9QUz_zIJqB8
- Chinese Architecture at http://www.youtube.com/watch?v=9hXtCrUNmVM
- Modern China at http://www.youtube.com/watch?v=kqIUNIE3XsQ&feature=related
- Opera House - virtual visit at http://www.youtube.com/watch?v=EI_FoDqOM4c
- China Beijing Olympic National Stadium - Bird's Nest (1of5) at http://www.youtube.com/watch?v=NqBdlnSxlis
- Golden Gate Bridge at http://www.youtube.com/watch?v=jWnGsBvFQSI

Session 2: Company Logo Design, and

Sessions 3 -and 4: Product Packaging Design

- Websites: Logo and packaging design.
  - LogoYes Sample Logos at http://www.logoyes.com/samplelogo.htm
  - Logo Design at http://images.google.com/images?hl=en&client=firefox-a&channel=s&rls=com.google:en-

US:official&hs=mt9&q=logo+design&um=1&ie=UTF-8&ei=eSv9SdzaC-CLtgep_ciRDA&sa=X&oi=image_result_group&resnum=4&ct=title

- Packaging design inspiration at http://dzineblog.com/2008/04/packaging-design-inspiration.html
- Beautiful and Expressive Packaging Design at http://www.smashingmagazine.com/2008/06/02/beautiful-and-expressive-packaging-design/

• YouTube videos: Logo and packaging design.

- Logo Design at http://www.youtube.com/watch?v=8-UyzjDOH40
- Logo Design - Logopalooza 2008 at http://www.youtube.com/watch?v=WKOcGwgMtGA
- 10 Trends That Will Define Logo Design In 2008 at http://www.youtube.com/watch?v=7vr8hDVvGK0&feature=related
- Logo Design Showcase #2 at http://www.youtube.com/watch?v=gQnTYXZtlIM&feature=related
- Minor Design Project - Sustainable Packaging at http://www.youtube.com/watch?v=KvIeY9Qa6E4&feature=related
- Less Is More: Sustainable Packaging at McDonald's at http://www.youtube.com/watch?v=r9ejG83lrX4&feature=related
- Eco-Friendly Packaging at http://www.youtube.com/watch?v=_9Fuo0iv0pI&feature=related
- New Product Packaging at http://www.youtube.com/watch?v=ByqQOHj4wUI&feature=related
- Lani Dig Your Dog packaging design by Langton Cherubino Group at http://www.youtube.com/watch?v=xv1VFj-UKC8
- Package Design at http://www.youtube.com/watch?v=MP2niGMUDHY&feature=related
- WHY® Design - Packaging & Branding Portfolio at http://www.youtube.com/watch?v=xZoxpyFkUaQ&feature=related

- Optic 3d-Design Packaging at http://www.youtube.com/watch?v=TLueVM2EXx4&feature=related
- Packaging: Years of Research for THIS at http://www.youtube.com/watch?v=WZUunSKzqeo&feature=related

Mini Lesson D (Industrial Product Design)

Session 1: Review: NCETE High School Engineering Design Process

- Websites: Design firms.
  - Bressler Group at http://www.bresslergroup.com/process/Intro.asp
  - Magnet Product Design and Development at http://www.magnetpdd.org/
  - Vitro at http://www.vitra.com/en-us/
  - SpeckDesign at http://www.speckdesign.com/
  - Reverse Engineering at http://en.wikipedia.org/wiki/Reverse_engineering
- YouTube videos: Industrial Product Design.
  - Industrial Product Design Company Service Portfolio at http://www.youtube.com/watch?v=2PbflB342Og
  - The making of product design rederings (engl. Teaser) at http://www.youtube.com/watch?v=Dfq0mYSm-s0&feature=related
  - MIT sketching at http://www.youtube.com/watch?v=NZNTgglPbUA&feature=related
  - Concept Sketching tutorial 01 at http://www.youtube.com/watch?v=Pk3vOJaBWLM&feature=related
  - Otis Interactive Product Design 2007 at http://www.youtube.com/watch?v=RNajvID_zTo&feature=related
  - Product Design demonstration at http://www.youtube.com/watch?v=pL2nvbR8wEw&feature=related
  - Product Design Manufacturing Challenge at http://www.youtube.com/watch?v=Js33O1N3in4&feature=related

- 3D Printing at http://www.youtube.com/watch?v=sNyIOPrXhd8&feature=related
- The Invention Process at http://www.youtube.com/watch?v=DuXmpY3UNos&feature=related
- Crazy inventions at http://www.youtube.com/watch?v=NpW717wBhso&feature=related
- Weird and Cool Inventions at http://www.youtube.com/watch?v=4A42DRWBODE&feature=related
- The worlds most amazing toy at http://www.youtube.com/watch?v=W2Vk4OIu1j4&feature=related
- Apparatus for Gyroscopic Propulsion Explained at http://www.youtube.com/watch?v=7Lka6d6DDBs&feature=related
- 3D Scanner at http://www.youtube.com/watch?v=6Mw8Q_v16dc&feature=related
- Prototype at http://en.wikipedia.org/wiki/Prototype

Session 2: Product Design Related Issues (Ergonomics, Product Safety, UL Testing, Patent Application)

- Websites: Ergonomics and product safety.
  - Ergonomics at http://en.wikipedia.org/wiki/Ergonomics
  - Ergobuyer® New Products at http://www.ergoweb.com/ergobuyer/index.cfm?fuseaction=page.display&page_id=24
  - ErgoWeb at http://www.ergoweb.com/
- YouTube videos: Ergonomics and product safety.
  - Work Station Ergonomics at http://www.youtube.com/watch?v=KUU6FYxE0YU
  - COMPUTER MOUSE PAIN KILLER (COOL ERGONOMIC VIDEO) at http://www.youtube.com/watch?v=8cyumcU_3G8&feature=related
  - Humanscale Ergonomics at http://www.youtube.com/watch?v=S_F-yaQ4Xqc&feature=related

- Ergonomics - Corporate Educational Video at http://www.youtube.com/watch?v=KC6nYJ0F6tU&feature=related
- Design Ergonomics - Dr. Ahearn - EP Video at http://www.youtube.com/watch?v=dIHrpeSivcM&feature=related
- Concord Travel System Product Features – Kiddicare at http://www.youtube.com/watch?v=jzk22rNPydo
- Ladder Safety Accessory Product - Lock Jaw Ladder Grip at http://www.youtube.com/watch?v=g-tjpOAJ6Ms

Mini Lesson E (Manufacturing and Engineering Economics)

Sessions 1 and 2:

- Websites: Manufacturing processes.
  - Manufacturing at http://en.wikipedia.org/wiki/Manufacturing
  - eFunda: Engineering *Processes* at http://www.efunda.com/processes/processes_home/process.cfm
  - Computer Integrated Manufacturing & Robotics at http://iew3.technion.ac.il/Labs/Cim/
- YouTube videos: Manufacturing processes.
  - Resin Casting at http://www.youtube.com/watch?v=kP1Nij-elyQ;
  - CNC Cutting a Face at http://www.youtube.com/watch?v=VaVr89FO_FE&feature=related
  - Mastercam Extreme Machining at http://www.youtube.com/watch?v=qLJxMUw51N8&feature=related
  - Mastercam Milling at http://www.youtube.com/watch?v=a-jxQ55Z8E4&feature=related
  - Sculpting a Womans Face at http://www.youtube.com/watch?v=euo8IKf2CuQ&feature=related
  - Mastercam's High Speed Machining at http://www.youtube.com/watch?v=LLC25KbCTxs&feature=related

- Plastic Injection Molding at http://www.youtube.com/watch?v=bit-D1NnfjI
- Blow Molding at http://www.youtube.com/watch?v=ynsS2afrUzE&feature=related
- Compression Molding at http://www.youtube.com/watch?v=Kh_PO9O4BAs&feature=channel
- Casting at http://www.youtube.com/watch?v=PIneaDTZ16g&feature=channel
- Gears & Gear Manufacturing at http://www.youtube.com/watch?v=2K45B6tDqsg&feature=related
- Forging at http://www.youtube.com/watch?v=tLRkOupbARM&feature=related
- Tube Bending at http://www.youtube.com/watch?v=9CM6Rf4MqYo&feature=channel
- Roll Forming at http://www.youtube.com/watch?v=xGLHjyPdDBI&feature=channel
- Plastic Thermoforming at http://www.youtube.com/watch?v=U60mdDW5Ulc&feature=channel
- Die Casting at http://www.youtube.com/watch?v=1AgDGLNE6Es&feature=channel
- Sheet Metal Coil Processing at http://www.youtube.com/watch?v=9bQiZ8njSiA&feature=channel
- Metal finishing process at http://www.youtube.com/watch?v=y21Zi_MY9wA
- Flat-line finishing process in action at http://www.youtube.com/watch?v=7fvQnhHq44M&feature=related
- Fletcher Robinson hand forged cutlery - the finishing process at http://www.youtube.com/watch?v=s8KzF6titxE
- Porous Metal & MIM : DigInfo at http://www.youtube.com/watch?v=VJ6HhusCLPk
- HHO Machine Assembly Process 3-30-2008 at http://www.youtube.com/watch?v=QTYCfaw2_Fk

- Robotic Assembly with Vision System - Automotive parts at http://www.youtube.com/watch?v=8A1Sujs3m4k

Sessions 3 and 4:

- Websites:
  - Robotics and Computer-Integrated Manufacturing at http://www.elsevier.com/wps/find/journaldescription.cws_home/704/description#description
  - Industrial Robots for Sale - Industrial Automation at http://www.robots.com/robots.php
  - The Role of Robotics in Flexible Manufacturing at http://www.assemblymag.com/Articles/Web_Exclusive/BNP_GUID_9-5-2006_A_10000000000000542368
- YouTube videos:
  - Manufacturing Robots Automated Assembly at http://www.youtube.com/watch?v=BKnXWMPbCyc
  - New Mini Production Video at http://www.youtube.com/watch?v=jypJlhoLwHA&feature=related
  - Fastening & Assembly at http://www.youtube.com/watch?v=KI83-OoY7mU&feature=related

Internet Sources (Websites, Videos, online Calculators) for STEM Topics

NASA Web Sites

NASA provides well-developed STEM instructional materials for K-12 through college applications.

- NASA Education: General information about NASA's Education Program (www.education.nasa.gov).
- NASA Educational Materials: Search engine for STEM Teaching Materials, such as Engineering Challenges (*Figure 9A*), etc. (http://search.nasa.gov/search/edFilterSearch.jsp?empty=true).

- NASA Education TV Schedule: Science instructional online videos (http://www.nasa.gov/audience/foreducators/topnav/schedule/about/index.html).

- NASA Image Exchange: Science-related image source (http://nix.nasa.gov/).

- Marshall Space Flight Center Image Exchange: Science-related image source (http://mix.msfc.nasa.gov/).

- NASA Resources for Instructor (Instructional materials): Central Operation of Resources for Educators (CORE) was established for the national and international distribution of NASA-produced educational materials in multimedia format. Educators can obtain a catalogue and an order form by one of the following methods:

  NASA CORELorain County Joint Vocational School15181 Route 58 SouthOberlin, OH 44074-9799Phone: (440) 775-1400FAX: (440) 775-1460 E-mail *nasaco@leeca.org*. Home Page: http://education.nasa.gov/edprograms/core/home/index.html

- Educator Resource Center Network (ERCN): General network information for instructors (http://www.nasa.gov/audience/foreducators/ERCN.html).

- Contact for Educators: Contact information listed by states (http://www.nasa.gov/audience/foreducators/9-12/contacts/ERCN_Field_Center_Listing.html).

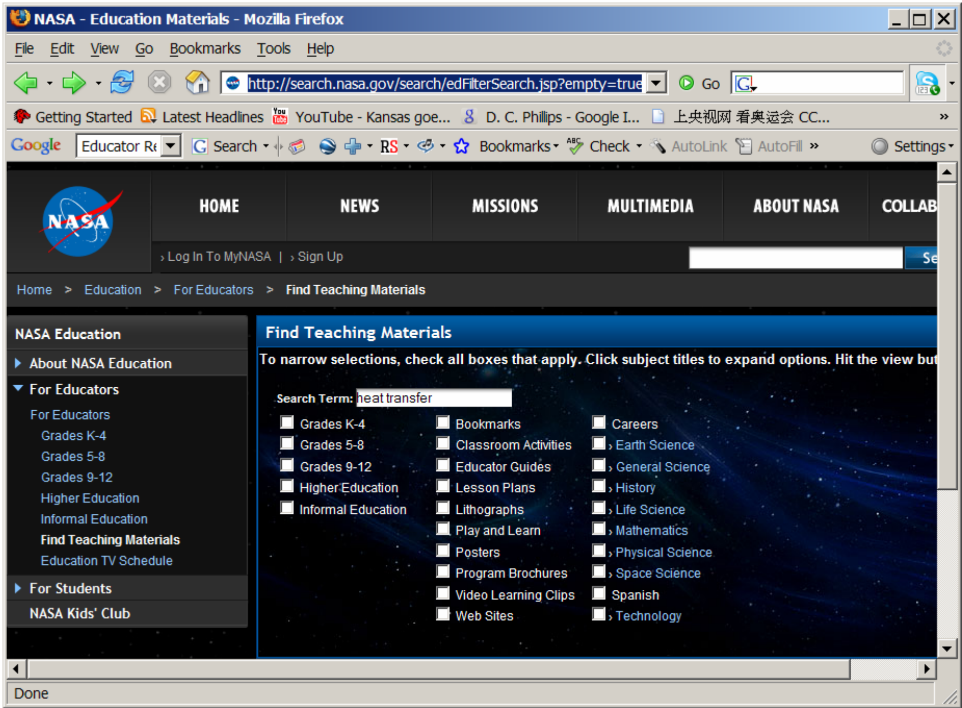
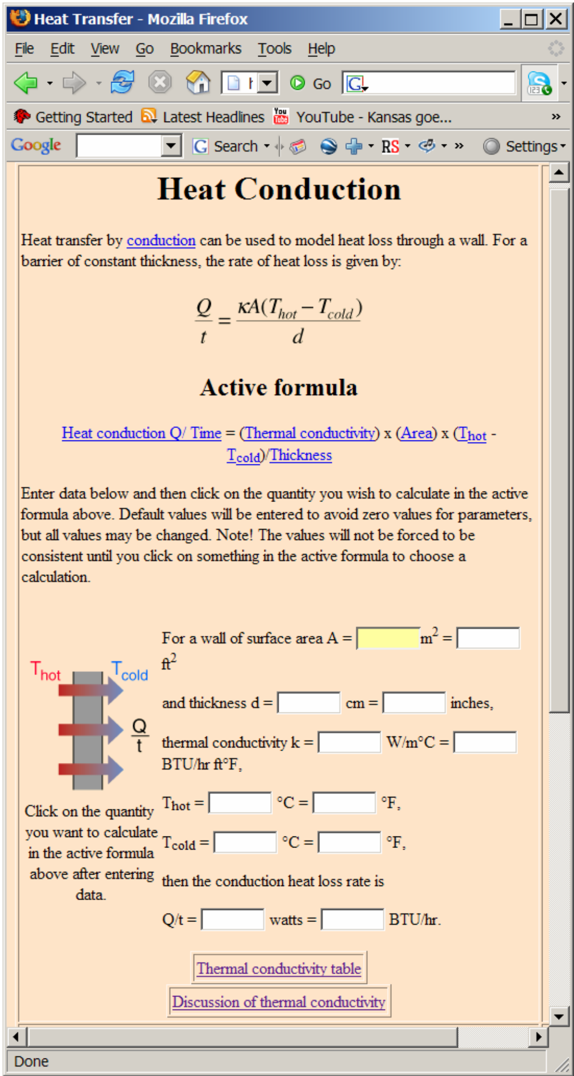


Figure 9A. NASA search engine for educational materials.

HyperPhysics site

HyperPhysics provides well-developed instructional materials for physics, including tutorial, discussion, tables of data, online calculators and others (*Figure 9B*). It won a Merlot Classic Award winner for 2005, and "was honored because of its comprehensive coverage of most of physics, the creative use of multimedia and linking, and the impact it has had on students worldwide. Online tutorials cover a wide range of physics topics, including modern physics and astronomy. Material is organized through extensive concept maps."

- Home Page: The search engine for Physics topics at http://hyperphysics.phy-astr.gsu.edu/Hbase/hframe.html (*Figure 9C*)


Heat Transfer - Mozilla Firefox

Heat Conduction

Heat transfer by conduction can be used to model heat loss through a wall. For a barrier of constant thickness, the rate of heat loss is given by:

$$\frac{Q}{t} = \frac{\kappa A(T_{hot} - T_{cold})}{d}$$

Active formula

Heat conduction Q/ Time = (Thermal conductivity) x (Area) x (T_{hot} - T_{cold})/Thickness

Enter data below and then click on the quantity you wish to calculate in the active formula above. Default values will be entered to avoid zero values for parameters, but all values may be changed. Note! The values will not be forced to be consistent until you click on something in the active formula to choose a calculation.

For a wall of surface area A = ____ m^2 = ____ ft^2

and thickness d = ____ cm = ____ inches,

thermal conductivity k = ____ W/m°C = ____ BTU/hr ft°F,

T_{hot} = ____ °C = ____ °F,

T_{cold} = ____ °C = ____ °F,

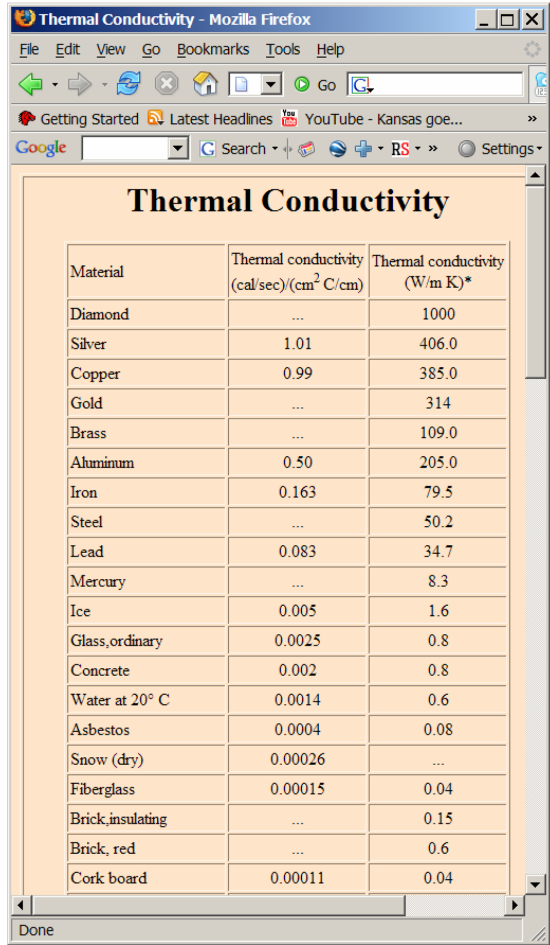
then the conduction heat loss rate is

Q/t = ____ watts = ____ BTU/hr.

Thermal conductivity table

Discussion of thermal conductivity

Done


Thermal Conductivity - Mozilla Firefox

Thermal Conductivity

Material	Thermal conductivity (cal/sec)/(cm^2 C/cm)	Thermal conductivity (W/m K)*
Diamond	...	1000
Silver	1.01	406.0
Copper	0.99	385.0
Gold	...	314
Brass	...	109.0
Aluminum	0.50	205.0
Iron	0.163	79.5
Steel	...	50.2
Lead	0.083	34.7
Mercury	...	8.3
Ice	0.005	1.6
Glass,ordinary	0.0025	0.8
Concrete	0.002	0.8
Water at 20° C	0.0014	0.6
Asbestos	0.0004	0.08
Snow (dry)	0.00026	...
Fiberglass	0.00015	0.04
Brick,insulating	...	0.15
Brick, red	...	0.6
Cork board	0.00011	0.04

Done

Figure 9B. HyperPhysics Heat Conduction online calculator and Thermal Conductivity Table

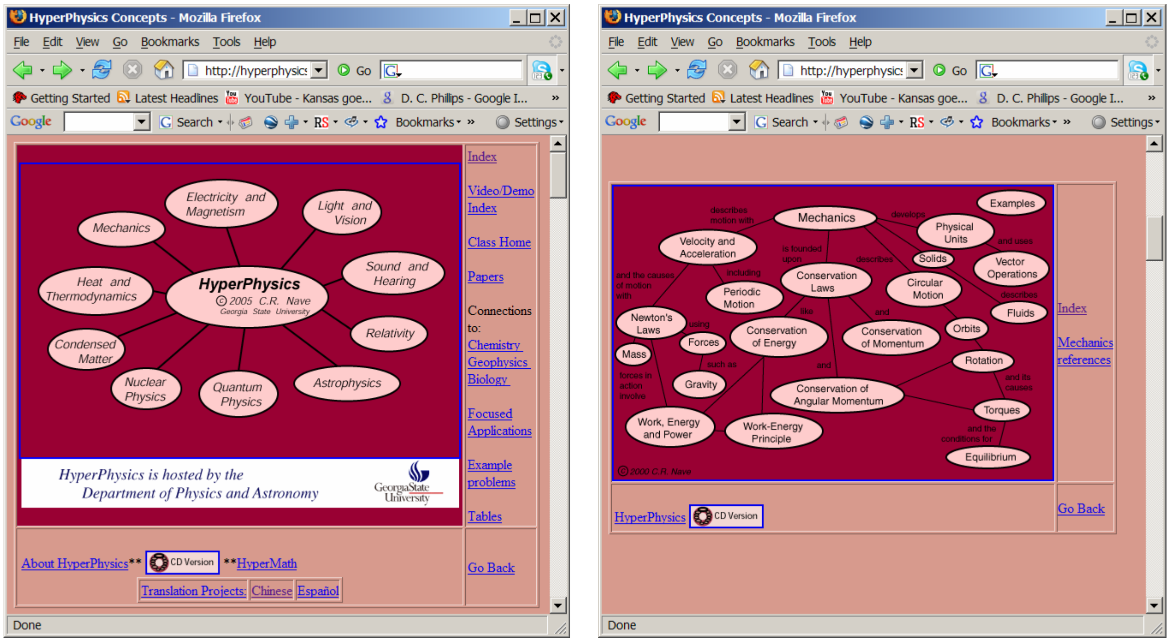


Figure 9C. HyperPhysics Home Page (Clicking an oval leads to a topic home page).

Student Design Idea Evaluation Sheet

To be attached at the end of the following student reports:

- Group and Company Report on Design of New Food Cooking Electro-Thermal Interface and Food Containers
- Logo or Packaging Design

Note: This form is for evaluation of individual student's design ideas (as recorded in Engineer's Notebook, and in the above report) ONLY. This is NOT for evaluating the final design results of the whole class, which will use:

- Engineering Design Challenge Evaluation Form (Appendix EDC-EF); and
- Engineering Design Challenge Portfolio Evaluation Form (Appendix EDC-EF).

Student Design Idea Evaluation Sheet

Group Name: ______________________ Date: ___________Version #: ____

Group Members: ____

Part Name: ________________________ Mini Lesson Label: ____________

Design Phase

1. Sketch the part design, with (1) orthographic and isometric views, dimensions and notes for Food Cooking Electro-Thermal Interface and Food Containers; or (2) sketch and color pencil rendering of logo and packaging (with both development and folded views).

2. Why did your group select or reject the above design?

____

____

____

____

Instructor Evaluation

1. Engineering predictive analysis:
____

2. Creativity:
____

3. Functionality:
____

4. Ergonomics:
____

5. Aesthetics:
____

6. Ease of manufacturing:
____

7. Others:
____

____

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Materials Lists for Prototyping

To be filled at the end of Mini Lesson B (Materials Selection).

Materials List for Prototyping

Date Needed	Item	Quantity	Available at School's own Facility/Outside Vendor Name and Phone Number	Cost
Metal Stock Materials				
Plastic Stock Materials				
Ceramic Forming Materials				
			Total Cost:	

Glossary

Definitions extracted May 2, 2009, from Wikipedia, the free encyclopedia.

- Reverse Engineering: "The process of discovering the technological principles of a device, object or system through analysis of its structure, function and operation. It often involves taking something (e.g., a mechanical device, electronic component, or software program) apart and analyzing its workings in detail to be used in maintenance, or to try to make a new device or program that does the same thing without copying anything from the original."

- Potentiometer: "A three-terminal resistor with a sliding contact that forms an adjustable voltage divider. If only two terminals are used (one side and the wiper), it acts as a variable resistor or Rheostat. Potentiometers are commonly used to control electrical devices such as a volume control of a radio. Potentiometers operated by a mechanism can be used as position transducers, for example, in a joystick."

- Heat Transfer: "The transition of thermal energy or simply heat from a hotter object to a cooler object."

- Aesthetics: "The study of sensory or sensori-emotional values, sometimes called judgments of sentiment and taste. More broadly, scholars in the field define aesthetics as 'critical reflection on art, culture and nature.'"

- Ergonomics: "The scientific discipline concerned with designing according to human needs, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. The field is also called human engineering, and human factors."

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