The Impact of Materials on Society
Module 8 –Iron and Steel - Outline of Instruction for Faculty

This week introduces the materials science behind the smelting of iron and fabrication of steel. The mass industrial manipulation of iron ushered in the modern Industrial Revolution. This module looks at the entrepreneur Andrew Carnegie, the creation of the steel industry, and industrial innovation, and uses lessons learned to predict how the growing use of new magnesium alloys will shape business and industry. This includes the concept of alloying with carbon and the iron carbon phase diagram. The history of steel is discussed from primitive times through the industrial revolution. The process of innovating with a new material on a mass market level has winners and losers; understanding how making new materials may require the re-ordering of social, political, and economic systems enables us to anticipate important consequences. The birth of US Steel and the concept of creative destruction is introduced and subsequently applied to the modern material magnesium which is replacing steel in many new applications.

Module Objectives:

Students will:

- identify the properties of iron and steel
- identify the properties of magnesium alloys
- discover the uses and applications of iron both historically and in modern times
- examine the role of workers and organized labor in materials manufacturing
- discover the business economics of materials production

Student Reading Assignment before Day 1

Read excerpt (pp. 83-97, 203-214) from
Sass, Stephen L. (1998/2011) *The Substance of Civilization*. New York: Arcade Publishing.

Day 1 Class – Material Science & Engineering Lecture on Clay

Material Science Professor gives an overview of Iron & Steel

Materials Science Lessons

This lecture reviews the properties of iron and steel, the history of iron making from early furnace designs to modern steel making, the concept of the iron carbon phase diagram and the different forms of alloys (wrought iron, steel, cast iron) that exist and why. The role carbon plays on the properties of these various alloys is discussed.

Day 1 Lecture Development Resources:

1. **Lecture:** Iron and Steel PPT slides
2. **Sample Lecture Video:** Iron and Steel Lecture (19:49) (Transcript)

Excerpts from Kevin Jones' lecture

3. **Demo Video:** Iron Experiment (3:52)
4. **Demo Video:** Dislocation Demonstration (2:33)

Classroom Demo: Fe_3O_4 powder is placed in a graphite crucible and under a torch is reduced to iron which is subsequently picked up by a magnet.

Student Reading Assignment before Day 2
Read: *Carnegie, Creative Destruction and American Steel* by Prof. Sean Adams

Abstract: This chapter uses the rise of Carnegie Steel as a case study to explore the social and economic context of materials. In the nineteenth-century United States, steel became a vital element of industrial growth, and Andrew Carnegie revolutionized its production through a system of "hard driving" at his steel mills outside of Pittsburgh, Pennsylvania. This is an example of the economic theory of "creative destruction," in which innovation in technology and the organization of the shop floor replaces longstanding institutions and practices in the production of materials. As a result, there are both gains to society—in this case cheap steel for the construction of things like buildings and railroads—but also drawbacks for workers and companies that tried to compete with Carnegie. In sum, innovation in the manufacture of materials can be a double-edged sword.

Day 2 Class – Lecture on Creative Destruction and Steel

Guest Professor presents Carnegie, Creative Destruction and American Steel; a lecture that outlines the historical context of the rise of American steel, with a focus on the business career of Andrew Carnegie. Carnegie Steel transformed the process of making steel through a rearrangement of the shop floor, the adoption of new techniques, and ruthless competition. All along the way, the notion of "creative destruction" in entrepreneurship, in which older routines are replaced by dynamic new ones, is an organizing theme that allows students to see the winners and losers during industrial transformations.

Social Lesson: The concept of **creative destruction** is introduced and understanding how this is applicable to modern innovation can facilitate successful business practices.

Day 2 Lecture Development Resources:

1. **Lecture:** Andrew Carnegie, Steel and Creative Destruction (PPT) slides by Prof. Sean Adams (UF)

Student Video and Homework Assignment before Day 3
Watch: Magnesium Alloys (9:57) (Transcript)

As you watch the video, consider answers to the following questions:

a. What current demands—both social and economic--are leading materials scientists to develop lightweight materials for use in the 21st century?
b. How do the properties of existing materials limit the design of products like automotive vehicle bodies or airplane parts?
c. What new technologies are allowing scientists to develop and apply lightweight materials for industrial use?
d. What will it take to make lightweight materials widely usable?
e. How might the growing use of lightweight materials in one industry affect other manufacturers, suppliers, or inventors? In other words, might these new materials cause any creative destruction in the same way that steel did in 19th century America?

Day 2 Individual Assignment:

Assignment: Module 8—Individual Homework Assignment (Word)
Magnesium Alloys Homework Essay due start of class Day 3

Please answer the questions in either bullet points or full sentences. Your response will probably take ½ to 1 page. Assignment will be graded out of 2 points on effort, use of the lecture, video, and reading materials, and thoughtful reflection. Be sure your name is on the paper. We'll build on your responses with the in-class group activity on Day 3.

Day 3 Class – Flipped Classroom Activity on Magnesium Alloys

Day 3 Classroom Activity: Magnesium Alloys, understanding how Creative Destruction applies to new innovations.

Class today should begin with a short lecture to recap the main points about iron, steel and magnesium alloys and connect them to the homework assignments, before the students break out into their flipped classroom groups. During group work, the instructors should circulate amongst the groups to check understandings. After group work, a few minutes should be left for sharing out findings with the class to verify and correct misunderstandings.
Students will turn in homework at start of class.

Using Carnegie's experience with steel as a case study and blueprint, think about a plan to develop a firm that specializes some aspect in the production or application of Mg alloys.

Part 1 – What is your firm's product? You raise a fixed amount of capital from the venture capital community. In order to gain a foothold in the market, would you focus on manufacturing techniques? R&D? Marketing and publicity? If you decide to pursue all three of these strategies, roughly what proportion of your resources would you devote to each area and why?

Part 2 - Are there any interests in a competing industry—suppliers, manufacturers, dealers, customers, users—that you think would be resistant or opposed to your new firm's product? What might you do to address their concerns?

- Refer to Day 3 In-Class Activity: Magnesium Alloys worksheet for specific instructions.
- Refer to the rubric for grading criteria.

Your grade will be determined from the following criteria.

Grading Rubric.

5= Responses are appropriate, comprehensive, and indicate thoughtful engagement with the information and concepts from the lecture, readings, and videos. Novel ideas, creativity, and attention to complexity are a plus.

4= Good effort. Responses and arguments are not as clearly presented, or as comprehensive and thoughtful as in a full credit answer.

3= Responses are less appropriate to the assignment, less thoughtful and engaged, with less complete information. Errors in grammar, punctuation and or sentence structure will also result in loss of points.

2= Responses are incomplete, showing little effort, thought, or use of preparatory materials.

1= Responses are not consistent with preparatory materials. Assignment is badly incomplete. Next to no effort.

Day 3 Lecture Development Resources:

1. **In-Class Activity:** Magnesium Alloys handout (Word)

Complete Impact Paradigm Assignment:

Thinking about the material that we covered in this week's unit, add another question to the impact paradigm.

- **Assignment:** Module 8—Impact Paradigm Individual Homework Assignment (Word)

Additional Resources

Online Course Module

a. View the online Module 8 in Word or PDF format
b. Available soon: The full online course to upload to your Learning Management System. Contact Kevin Jones at kjones@eng.ufl.edu or Pamela Hupp at hupp@mrs.org for more information.

Videos:

a. Alan Taub. "Lightweight Automotive Materials" (15:38) video

Articles and Books:

a. Carnegie, Andrew. *Autobiography of Andrew Carnegie.* Boston: Houghton, 1920.