The Impact of Materials on Society
Module 2 - Clay and Rare Earths – Outline of Instruction for Faculty

This module focuses on the most primal material—earth itself, in the form of clay—as used in the deep past, in the Neolithic "Age of Clay," and contrasts it with materials very much of the present and future: rare earth elements. As different as they may seem, clay and rare earth elements are similar not only as "earthy materials" but in terms of how humans have become inexorably dependent on them, even as these things are dependent on humans.

Module Objectives

Students will:

- identify the properties of clay
- discover the uses and applications of clay both historically and in modern times
- identify the properties of rare earth materials
- discover the uses and applications of rare earth elements in modern times and projecting into the future
- analyze the entanglements of humans and materials using Hodder's model
- differentiate affordances from constraints and potential from actualized properties

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Student Reading Assignment before Day 1

Read excerpt (pp. 13-37) from
Sass, Stephen L. (1998/2011) *The Substance of Civilization*. New York: Arcade Publishing.

Day 1 Class – Material Science & Engineering Lecture on Clay

Materials Science Professor gives an overview of clay: History, early uses and applications of clay, physical-chemical properties of clay, and an introduction to rare earths and their properties

Materials Science Lessons

The goal from a materials science and engineering standpoint of this module is to discuss the properties of one of the oldest materials people have manipulated. The properties of clay depend not only on the structure and chemistry of the particles but their size. In addition this was the first material to be manipulated irreversibly upon heating as it is converted from clay to a ceramic upon sintering.

Day 1 Lecture Development Resources:

1. **Lecture:** Clay PPT slides
2. **Sample Lecture Video:** Clay (14:26) (Transcript)
   Excerpts from Kevin Jones' lecture

Classroom Demo: bring sample of clay, Neodymium magnets

Student Reading Assignment before Day 2

Read e-Textbook Chapter: *The Entanglement of Earth in the Age of Clay* by Susan D. Gillespie

> *Abstract: This chapter showcases human engagements with the most primal material of all–earth itself–beginning in the Neolithic period, when people relied on domesticated plants and animals for their livelihood. The Neolithic has also been called the Age of Clay because clay and soils were critical materials for many aspects of daily life. A case study of an important Neolithic settlement, Çatalhöyük, demonstrates how people and clay became interdependent on each other, resulting in an "entanglement" that influenced human actions and values. The Neolithic entanglement with clay, multiplied countless times all over the globe, led to significant historical changes in human society that still reverberate today. This case study also provides general insights for understanding the relationships between humans and materials. How people engage with the potential and actualized properties of materials in production processes is key to understanding the historical trajectories of the impacts of materials on societies.*

Day 2 Class – Lecture on The Early Entanglements of Clay

Guest Humanities/Archaeology Professor presents The Entanglement of Earth in the Age of Clay.

Watch video: Earthenware pottery-making skills in Botswana's Kgatleng District (10:00) video at start of lecture

Social Lessons:

1) **Entanglement:** Humans and things develop interdependencies (entanglements) that trap them and constrain or limit their actions. The entanglement model developed by Ian Hodder is a method for analyzing human-material relationships: humans depend on things, things depend on other things, things depend on humans; thus, humans depend on things that depend on other things and on humans.

2) **Affordances**: Humans engage with the properties of materials, not an essentialized or universally recognized substance such as "gold" or "clay" or "stone." These materials come bundled with both potential properties, which are not realized or possibly even recognized, and actualized properties, which are recognized and put to use in a particular social context. The actualized properties that are advantageous to humans are called affordances. Affordances go beyond properties inherent to the materials themselves and depend on circumstances of use—are they available, abundant, cheap to use, easy to transport, durable?

Whether properties are affordances or not requires social agreement. Disadvantageous properties are constraints on human intentions and actions. Constraints may also be potential or actualized properties, and are also based on social conventions. Thus the very same properties of materials may be potential or actualized, affordances or constraints, depending on the circumstances of their application. And, similarly, we may realize new uses for the same materials centuries in the future if social conventions or processing techniques change.

3) **Social Change**: Social or historical change is often believed to result from human ingenuity or invention, or alternatively, from the introduction of new material technologies. In fact, neither factor alone produces change. Change occurs through the interactions of humans with material properties over time.

Day 2 Lecture Development Resources:

Lecture: The Entanglement of Clay at Çatalhöyük (PPT) slides by Prof. Susan Gillespie (UF)
Lecture: Material Properties (PPT) slides by Prof. Susan Gillespie (UF)

Classroom Demo: bring archaeological clay artifacts.

Student Video and Homework Assignments before Day 3

Watch video: Rare Earths (17:16) (Transcript)

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

a. What precisely are "rare earth elements"? What are some of their enabling properties?
b. In what ways are societies today dependent on rare earth elements? What are some of the important everyday examples of consumer items using rare earth elements?
c. What role do rare earth elements play in "green" (sustainable) technologies?
d. How would you explain the "scarcity" of rare earth elements? Are they actually "rare"?
e. What does it mean for rare earth elements to be "byproducts"? Why does that make mining solely for rare earth elements inefficient and expensive?
f. What social and political factors complicate access to rare earth elements?
g. What are the different ways that the technologies for utilizing rare earth elements can be made more sustainable?
h. What are some of the likely future applications of rare earth elements? For what problems can rare earth elements be part of a solution?

Day 2 Individual Assignment:
Read Assignment: Module 2—Individual Homework Assignment (Word)
Rare Earths Homework Essay due start of class Day 3

Create a list of at least 5 things in your apartment/dorm room or among your possessions that you regularly use that contain rare earth elements. If you know which specific elements they may contain, indicate that. Pick one of those 5 items and write a brief essay of how you are "entangled" with it, drawing on the premises of Ian Hodder's entanglement model. Sketch a "tanglegram" to graphically represent the various ways you depend on that thing, it depends on you, and it depends on other things and materials. See instructions for creating a tanglegram.

Please write in essay form (full sentences in paragraphs), typed double-space (11-12 pt font), minimally 1 full page. Assignment will be graded out of 10 points on effort, use of the lecture, video, and reading materials, and thoughtful reflection. Be sure your name is on the paper. A cover page is not necessary.

Day 3 Class – Flipped Classroom Activity on Entanglement with Rare Earths

Key Concepts: Rare earth elements are a class of materials that when alloyed or mixed with other elements can offer a range of fascinating property changes from fluorescence to increased magnetism. Many of the modern sustainable systems like windmills, electric vehicles and LED lighting rely on rare earth elements. However, as we learned from "The Age of Clay", our dependence upon rare earth elements for new technologies also make us dependent upon the people and processes for sourcing these elements. As a result, political challenges with where rare earths are mined continue to be a concern for these critical materials.

Humans and things develop interdependencies (entanglements) that trap them and constrain or limit their actions. The entanglement model developed by Ian Hodder is a method for analysis: humans depend on things, things depend on other things, things depend on humans; thus, humans depend on things that depend on other things and on humans. Entanglement is a method, applicable in any circumstance, for understanding people-thing interactions; their social, political, economic, and cultural contexts; and how they form historical trajectories that are difficult to break out of and make it unlikely that new technologies or materials will be adopted if they don't fit the current entanglements.

Day 3 Classroom Activity: The entanglement of rare earth materials.

Class today should begin with a short lecture to recap the main points about rare earths 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 essays at start of class.
Show a video as students come into classroom, e.g., Global Race for Rare Earths

(10 minutes) Briefly reiterate the important points about Rare Earth Elements (REEs), their increasing usage especially in green technologies, and the difficulties (logistical, political, economical) of obtaining them. See short ppt. Day 3 Lecture: Rare Earths (PPT)

(10 minutes) Have students volunteer from their homework essays which objects with REEs they chose to write about and how they feel they have become entangled (interdependent) with them. Remind them that entanglement is not just dependency; it's interdependency.

(20 minutes) Divide the class into small groups. Have them share their thoughts from their essays. Then ask them to discuss in more general terms—and write out on paper--how humans are entangled with (trapped by) rare earths by going through the four premises. [See Day 3 – In Class Activity handout.] Challenge them to devise solutions to the problems of acquiring enough REEs and of the needed kinds to create sustainable green technologies into the 21st century. How can we acquire more REEs? Can we do without them in certain applications? What about substitute chemistry? What are the political-economic consequences? Will recycling work?

Apply Ian Hodder's entanglement premises to the use of REEs today:

a. Draw a tanglegram that graphically displays our current entanglement with REEs (both general technologies and specific uses). (see instructions on how to draw a tanglegram)
   The tanglegram should specify in some way 1) how people are dependent on REES, 2) how REEs as "things" are dependent on other things, 3) how REEs, as things, are dependent on people; and thus the interdependencies of people and REEs.

b. Briefly explain why this is a form of "entrapment" and why it is unsustainable.
c. How does the historical trajectory of entanglement of REEs since the 20th century make it difficult to innovate new technologies, or even revert back to old technologies?

2. Brainstorm solutions. How can we create sustainable green technologies for the 21st century given the currently unsustainable entanglement of REEs? [bullet points okay in this section]
   a. What are potential engineering solutions?
   b. What are potential political and economic solutions?
   c. What are potential social and cultural solutions? (Consider social aspects of affordances and constraints.)

(10 minutes) wrap-up: class discussion; turn in papers (with names) for credit.

- Refer to Day 3 In-Class Activity: Rare Earth Entanglement 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 and indicate engagement with the preparatory material. Grammar, sentence structure and punctuation are correct.

4= Responses and arguments are not as clearly presented. Some minor issues with grammar, punctuation and or sentence structure.

3= Responses are not appropriate to the assignment and do not reinforce the physical and cultural properties of materials. Mistakes in grammar, punctuation and or sentence structure.

2= Responses are incomplete. Major problems with grammar, punctuation and or sentence structure.

1= Responses are inconsistent with material covered in class, videos, and readings. Missing elements of assignment. Poor grammar, punctuation and or sentence structure.

Day 3 Lecture Development Resources:

1. **Lecture:** Rare Earths PPT slides
2. **In-Class Activity:** Rare Earth Entanglement handout
3. **Instructions:** How to Make a Tanglegram handout
4. **Video:** Global Race for Rare Earths (10:17)

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

- Module 2—Impact Paradigm Individual Homework Assignment (Word)

Additional Resources

Online Course Module

a. View the online Module 2 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.

Articles:

a. King, Hobart. "REE—Rare Earth Elements and their Uses." Geology.com, Web.
b. *MRS RES Energy Critical Elements Final Report*
c. *MRS RES Securing Our Competitiveness*
d. Rare Earth Elements: Articles & Information
e. Rare Earth Elements Handbook

Videos:

a. Traditional clay processing in Botswana (10:00)
b. The Global Race for Rare Earths (10:17)

c. Alex King - Clay video (14:26) video