AC 2012-4179: REMODELING INSTRUCTIONAL MATERIALS FOR MORE EFFECTIVE LEARNING IN INTRODUCTORY MATERIALS CLASSES

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Remodeling Instructional Materials for more Effective Learning in Introductory Materials Courses

Abstract

Students have prior knowledge about how the world works, including preconceptions and misconceptions. For more effective learning, instructional materials and activities need to be restructured/remodeled to address misconceptions and knowledge gaps as informed by assessment of prior knowledge. In particular, we have explored and examined materials with regard to topics of language and operational definitions, types of graphical representations, real world applications, and explicit discussion of micro-macro scale connections between a material's microstructure and its macroscopic properties. In engineering education, instruction must build on students' knowledge of scientific phenomena and direct it toward its use in engineering applications. In this research, teaching and learning materials and activities have been remodeled by use of feedback from assessment results on a regular basis in order to enhance students' conceptual change for more effective learning. Here, we report on the research question, "How can instructional materials be modified and adjusted to promote conceptual change by using formative and summative assessment in an introductory materials class?" A socio-constructivist pedagogy with learning by conceptual change frames the discussion and analysis of results of this research-to-practice teaching and learning paper. Information from a materials concept inventory (MCI), pre-post topic concept quizzes, team activities, classroom dialogue and homework were used to remodel class notes and activities. To promote conceptual change we use analogical reasoning and cognitive dissonance learning tools that are integrated in class notes and team activities. Incorporating hard data in "explain and predict activities" forces students to address anomalies in their mental models and revise and remodel their conceptual frameworks. We have found increasing gains in pre-post topic concept quizzes and the MCI with remodeled materials. The effect of the approaches applied here to promote more effective conceptual change are discussed in terms of remodeling of instructional materials, activities, and tools in the classroom. Some general approaches to improving student performance are suggested.

Introduction

The science of learning is moving forward rapidly, as described in *How People Learn*: *Brain, Mind, Experience, and School*[1] , which summarizes and highlights some of the most important findings in the field of cognition of teaching and learning. One finding is that students bring their own experience to the classroom as prior knowledge about how the world works. This prior knowledge consists of preconceptions (which may or may not be correct) which may persist during instruction and act as barriers to learning. A second about how experts and novices learn and transfer knowledge suggests that, to develop competence, students must have deep content understanding and that their facts and ideas need to be organized in a conceptual framework that facilitates retrieval and transfer to new applications. A third is that research on performance of experts and on metacognition indicates learners can develop their own expertise by defining learning goals and monitoring their progress. The findings help guide engineering education research to develop innovative strategies in teaching and learning to enhance students' knowledge, skills, and understanding as recommended in the book, *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*[2]. We will use these three principles from How People Learn (HPL) and the results of student assessments to restructure course materials for more effective learning.

Issues and Challenges in Introductory Materials Courses.

The three HPL research-based principles have been used to modify instruction, student activities, and assessment to promote more effective learning. However, to better understand how to implement these principles within the framework of the introductory materials course, the issues and challenges of teaching and learning in the course were characterized and contrasted with traditional lecture-based approaches to teaching and learning. Specifically, for instructors to be more effective in an introductory materials course they must address Materials Course Instructional Issues (MCIIs) of:

1. *Connecting* macro-properties & micro-structure relationships at different length scales
2. *Uncovering and repairing* misconceptions and filling in knowledge gaps of materials concepts[3]
3. *Large* body of terminology > *400 new terms & > 100 new symbols & units*
4. *Lack of* class activities in materials texts for engaging students in their own learning
5. *Lack of* contextualization in materials texts which could help students see the value of abstract concepts when related to concrete engineering items
6. *Preparation-challenged* students who rarely read the text due to its volume and lack of context
7. *Decreasing* class attendance across a semester due to lack of student engagement perception of low value of lecture content that is similar to book and lack of awareness of student issues
8. *Withdrawal* of students from materials classes due to loss of value and interest in class

When classroom and student issues better articulated, it is possible to better align the three major HPL principles with improved class pedagogy, instructional materials, classroom management, and assessment tools. As such, the course materials have been redesigned because of improved instructor pedagogical content knowledge that can foster more effective teaching and learning. Relatively limited changes in course and classroom protocol, pedagogy, activities and assessments can result in enhanced motivation and achievement which are characteristic of more effective learning[4]. Such changes will be discussed in terms of the three HPL principles in conjunction with "Materials Course Issues".

Eliciting Students Prior Knowledge – How People Learn Principle

For the first HPL principle of "*eliciting students prior knowledge"* - misconceptions, and knowledge gaps, assessments were conducted at three time scales – semester, topic, and daily classes. Information from these assessments was used as feedback that informed instruction and materials were integrated for improving the classroom experience. The three time scale assessments are discussed below.

Semester Pre-Post Assessment Time Scale

A Pre-Semester Test with the Materials Concept Inventory (MCI) was administered to all students to assess baseline conceptual knowledge and reveal possible misconceptions and knowledge gaps. At the end of the course a *Post-Semester Test* was administered with the MCI to measure students' conceptual change and the effectiveness of instruction in repairing misconceptions and filling knowledge gaps. Misconceptions still persisting at course exit were considered to be "robust misconceptions" for which students have faulty mental models resistant to change. A typical MCI question is shown in Figure 1.

Example of a Robust Misconception

When a copper wire from a hardware store is heated and cooled it softens because

a) *bonds have been weakened* ***(favorite)***
b) it has fewer atomic level defects **(correct)**
c) it has more atomic level defects
d) density is lower
e) there is more space inside the crystal lattice

S02	Lecture:	*14% gain*
S11	Active:	*34% gain*

Figure 1. A question on the MCI and conceptual gains in lecture vs. active pedagogy

Topic Pre-Post Assessment Time Scale

For five of nine topics a *Pre-Topic Concept Quiz* was administered to assess baseline topic knowledge and to reveal topic misconceptions and knowledge gaps[5]. After instruction on the topic was completed, a *Post-Topic Concept Quiz* was administered to assess topic conceptual change and effectiveness of repairing misconceptions. Such results can be considered a measure of instructional effectiveness. Shown below in Figure 2 are typical responses for a given student on an Atomic Bonding Pre and Post Topic quizzes that show the extent of conceptual gains and misconception repair. A rubric was used to quantify the measure of conceptual gain. The responses below show significant gains in conceptual understanding, description (written and sketched) and application of concept models of bonding. However, the concept models were more aligned with models of bonding from chemistry rather than those used to represent bonding in engineering materials. For example, van der Waals bonding was illustrated with water molecules. However, van der Waals bonding is most important in 3-D solids in engineering materials for polymers. Such materials have weak van der Waals bonding between 1-D covalently bonded long polymer chains that are "held together" with the van der Waals bonding. This weak bonding accounts for the low melting points of polymers compared to the much higher melting points of primary bonded metals and ceramics. As such, instructional materials were modified to illustrate normative atomic bonding models for engineering materials and the relationship between bonding and such properties as melting point, elastic modulus, and coefficient of thermal expansion.

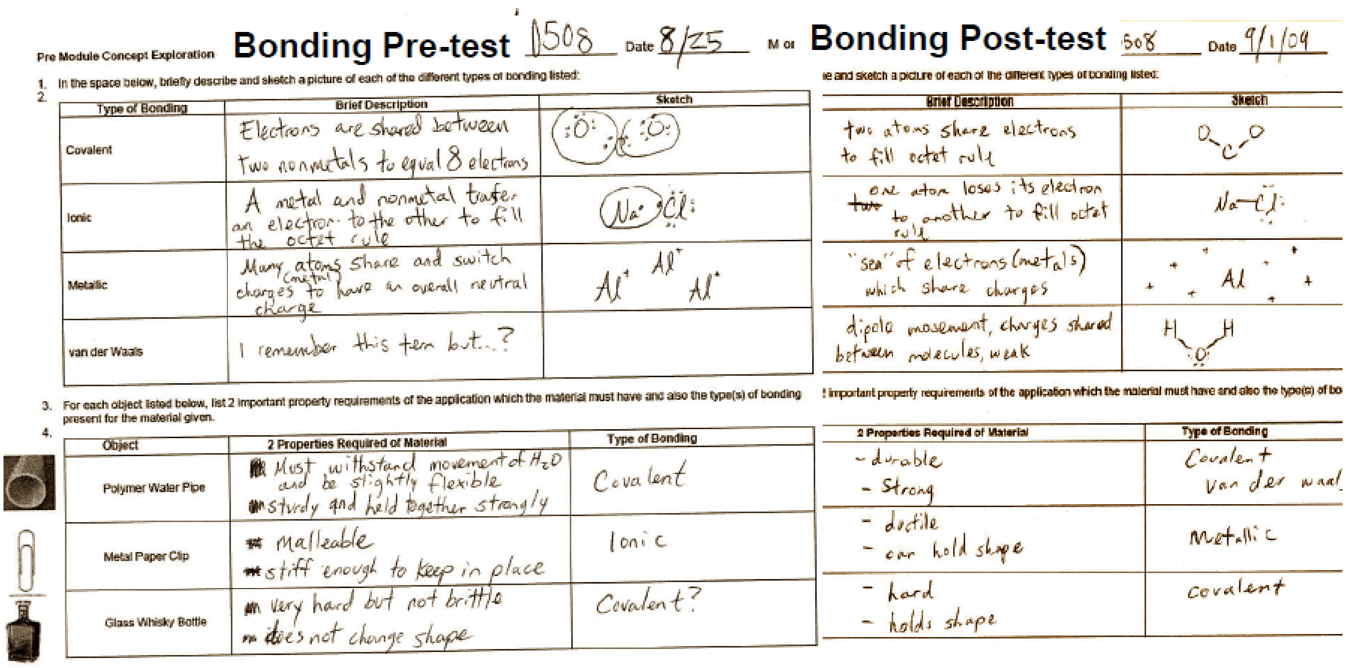


Figure 2. One student's Pre and Post Topic Quizzes for the area of atomic bonding.

Daily Post-Class Assessment Time Scale

Toward the end of each class students' experience in the classroom that day was assessed with *Daily Points of Reflection* writings on students' points of interest, muddiness and learning as seen in Figure 3. Results were entered into an Excel spreadsheet and then summarized and discussed at the very beginning of the next class with a *Reflection Point Commentary*. For many students the discussion of the major Muddiest Points helped clarify understanding of difficult concepts and clear up learning issues on the concepts. An example with typical results is shown in the figure below[6].

With respect to the three time scales, the most noticeable effect on the class was due to addressing the students' Muddiest Points, such as concepts, terminology, and calculations, immediately at the beginning of the class after the data was gathered. As such, the Reflection Points Class Start Commentary positively impacted students' motivation and learning as determined from self-assessment survey in which 73% of the class said that the Muddiest Point Commentary supported their learning. One surprising finding from the Daily Reflection Points was that many students lacked the skills necessary to read graphs, which is a point that will be discussed later.

Overall, the greatest effect related to the "*eliciting prior knowledge*" HPL principle was enhanced motivation and learning which positively impacted the three of the "Materials Course Issues":

1. *Connecting* macro-properties & micro-structure relationships at different length scales
2. *Uncovering and repairing* misconceptions and filling in knowledge gaps
3. *Withdrawal of* students in materials classes due to loss of interest in class

Points of Reflection on Today's Class

Letter + 4 digit number _______________ F M

Class Topic: _________________________ Date: _________________

Please briefly describe your insights on the following points from *today's* class.

• Point of Interest: **Describe what you found most interesting in today's class.**
How Interesting? (circle) Little Bit 1 2 3 4 5 Very Much

"Reading graphs is fun and is a great way to understand information =) "

• Muddiest Point: **Describe what was confusing or needed more detail.**
How Muddy? (circle) Little Bit 1 2 3 4 5 Very Much

"How can multiple phases be present simultaneously given same overall conditions?"
MUDDY POINTS DISCUSSED AT BEGINNING OF NEXT CLASS

• Learning Point: **Describe what you learned about how you learn?**

"It helps to talk things out with the group and teacher"

Figure 3. End-of-Class Daily Reflection sheet with typical student responses.

Future work on these assessments is being directed towards adapting the three types of assessment tools, the MCI, the Pre-Post Topic Quizzes, and the Points of Reflection, for running on cyber-enabled infrastructure web-sites. This will facilitate and expedite assessment data and analysis to better inform both students and the instructor of about how to address Materials Course Issues as well as provide data for the materials learning trajectory. Presently, the MCI has been uploaded on to the ciHub web site and a set of 104 ConcepTests (Clicker Questions) across nine topics has been loaded on to the AIChE Concept Warehouse web site. It would be quite desirable to locate the set of five Pre-Post Topic Quizzes and Points of Reflection assessments on the cyber enabled web sites also.

Classroom Engagement of Students – How People Learn Principle

For the second HPL principle of "Engage students to build deep content knowledge to form conceptual frameworks", there were two important changes made in content, activities, and pedagogy of the materials. The changes impacted six of the eight "Materials Course Issues" as described below.

The first change was modifying the class textbook slide set. Like most introductory materials texts, it sometimes tends to separate relationships between macroscopic processing and properties and micro-level material features from one another. This causes difficulty for students because they cannot see or understand the critical connection between a material's macroscopic properties and processing, and the underlying nano-level and micro-level structural features which control materials' properties and processing. In particular, fundamental foundational concepts about atomic bonding and crystal structure do not generally connect in the class textbook with macroscopic properties or processing or real-world contexts technological components, systems, processes, or real world events. Thus, these topics tend for students to lose relevance and their interest. As such, this issue was addressed with slide sets for the Atomic Bonding Topic and the Crystal Structure Topic being modified by incorporating activities, real-world contexts, and clearly articulated models of bonding and structure to address the issues described. Overall, these changes addressed the "Materials Course Issues" of:

1. *Connecting* macro-properties & micro-structure at different length scales
2. *Repairing* misconceptions and filling in knowledge gaps
4. *Lack of* class activities in materials texts for students to engage in own learning
5. *Lack of* real-world contexts in texts for showing value of concepts and problems

The second significant change was development and use of Concept Map Quizzes (CMQs). A CMQ (shown on the next page in Figure 4) is a concept map from which a set of terms or concepts or images has been removed from a level of boxes on a concept map and then placed in a "word bank" or "terminology bank." A student can then draw upon the "word bank" to put the words or terms into an appropriate box or bubble. The CMQs were used both as prior class Homework Preview Problems as well as a team-based classroom activity Class Summary Concept Map Quizzes. The Concept Map Quizzes uniquely address many HPL principles as well as "Materials Course Issues". These are described below and illustrated with an example Homework Preview Problem for Polymers.

- First, Concept Map Quizzes facilitate development of a student's conceptual framework on a particular topic by visually showing linkages, not only between important concept macro-micro linkages of a material, but also linkages to real world items and applications.
- Second, they connect multiple representations of a particular aspect of a material that can include visual, verbal, symbolic, structural, and definitional representations.
- Third, they promote concept and vocabulary building to facilitate assimilation of over 400 new terms in an introductory materials course.
- Fourth, they use *focused reading assignments* of typically only three to six pages of reading. Students will not open the book to read a 25-30 page assignment to prepare for a class, but they will read 3 – 6 pages to solve a CMQ which helps students prepare for the next class.
- Fifth, many students say that the CMQs are fun to solve, like a puzzle.
- Sixth, as a Preview Homework Problem, they provide a link from a given day's class topic to the next day's class topic to help connect prior knowledge with new knowledge.
- Seventh, used as a classroom team activity as a topic summary, they engage students in an enjoyable way that may contribute to course persistence in conjunction with other activities.

Concept Map Quizzes can address all earlier cited "Materials Course Issues" of:

1. *Connecting* macro-properties & micro-structure at different length scales
2. *Repairing* misconceptions and filling in knowledge gaps

3. *Large* body of terminology > *400 new terms & > 100 new symbols & units*
4. *Lack of* class activities in materials texts for students to engage in their own learning
5. *Lack of* contextualization in texts which could show students the value of abstract concepts when related to concrete engineering items
6. *Preparation-challenged* students who rarely read the text due to its volume and lack of context
7. *Decreasing* class attendance across a semester due to lack of student engagement & perception of low value of lecture content that is similar to book
8. *Withdrawal* of students from class due to loss of value and interest in class

In the future there are a number of goals related to building conceptual frameworks to be addressed. One is to incorporate Concept Map Quizzes on a cyber-enabled interface as a pre-class assessment tool. Another is to conduct discussions with focus groups about the impact of the classroom activities and the CMQs on their learning, attitudes, and conceptual framework building. Understanding student models and conceptual thinking will help define issues with content and concepts with an opportunity to use that knowledge to develop more effective teaching materials and strategies and more authentic assessments to measure student learning trajectories.

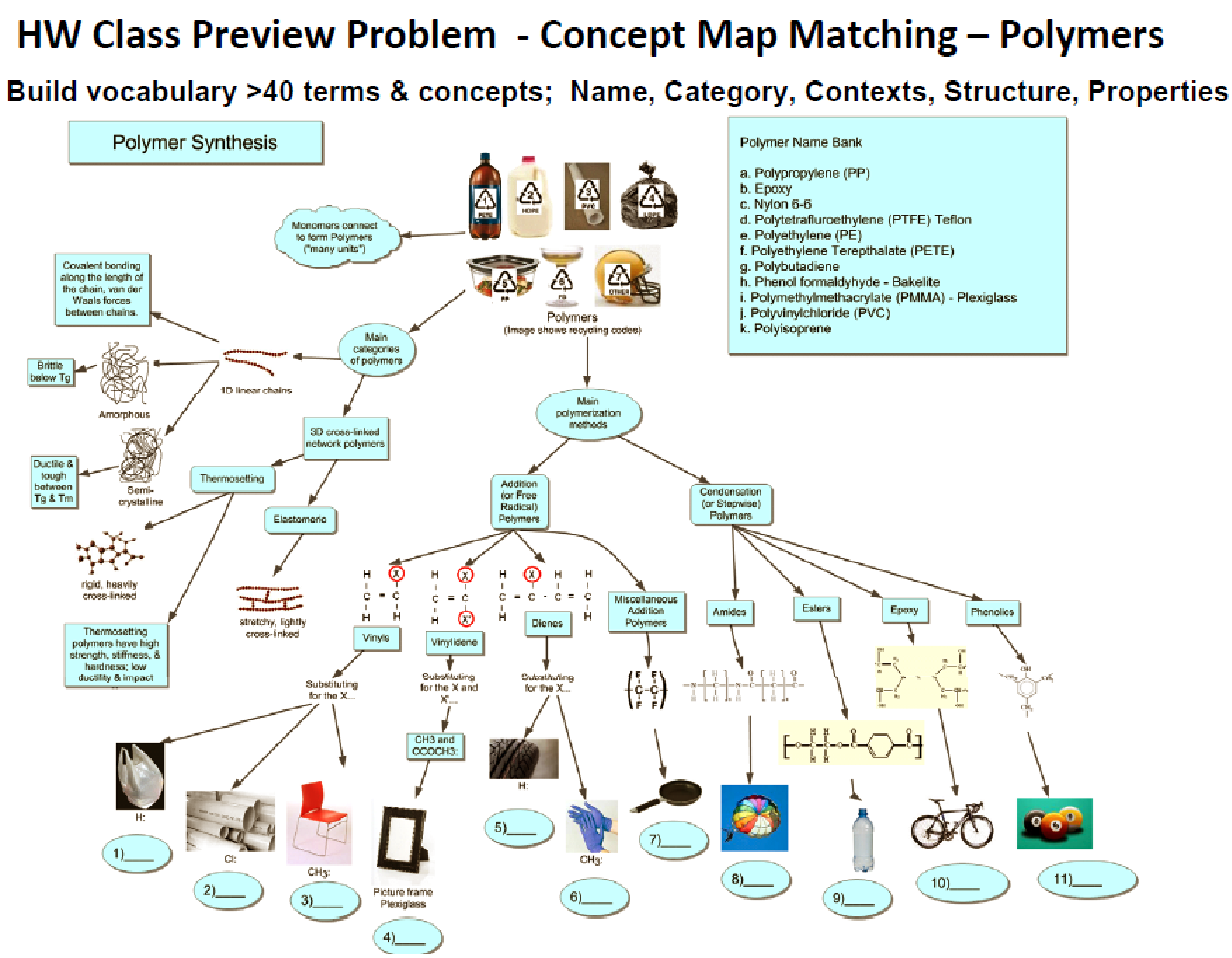


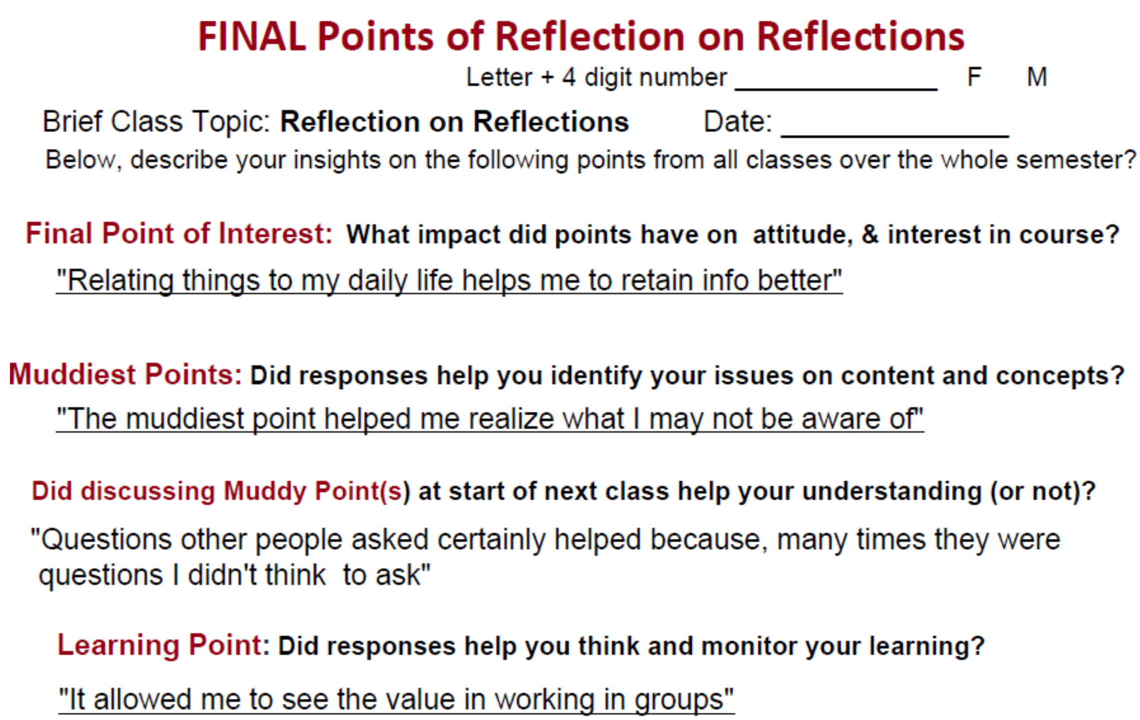
Figure 4. A Homework Preview Problem using a sort-and-match concept map for a polymers topic.

Encouraging Metacognition – How People Learn Principle

An important factor to improve students' motivations and learning is to *encourage metacognition, "so students are motivated to develop expertise by defining learning goals & monitoring own progress*" there were two important changes. One was the immediate Next Class feedback from the Daily Reflection Muddiest Point which addressed difficult concepts in the following class to help avoid persisting misunderstandings or misconceptions which could turn into conceptual barriers in the progression of learning on a given topic. The Class Start discussion also links the prior class material to the new class material and helps activate previously acquired knowledge. A second change was development of a new summative assessment tool to assess the impact on students of a full semester responses on Reflection Points. It is called the Reflection on Reflections assessment (or a Meta Reflection) administered at the end of the semester. It proved to be quite valuable for understanding and evaluating the impact of a whole semester of Reflection responses on student attitude and learning. Student comments were very positive and revealed the impact of the Reflections on student learning and attitude. These positive impact of these changes was enhanced by further modifications of the teaching materials and activities. As such, changes actually addressed the "Materials Course Instructional Issues" of:

5. *Lack of* real-world contexts in texts for showing value of concepts and problems
6. *Unread* book of unprepared students due to text volume, dryness, & no context
7. *Diminishing* class attendance in death by PowerPoint & lack of engagement
8. *Diminishing* persistence of students due to loss of interest in class

Future work will study possible correlations of Reflection responses to Pre-Post Topic Concept Quiz performance. Preliminary analysis of the responses indicated the quality of articulation of Daily Reflection Points may be correlated with performance on both Pre-Post Concept Quizzes and the MCI gains. An example of a Meta Reflection form and samples of comments is shown below in Figure 5.


FINAL Points of Reflection on Reflections

Letter + 4 digit number ______________ F M

Brief Class Topic: **Reflection on Reflections** Date: ______________

Below, describe your insights on the following points from all classes over the whole semester?

Final Point of Interest: What impact did points have on attitude, & interest in course?

"Relating things to my daily life helps me to retain info better"

Muddiest Points: Did responses help you identify your issues on content and concepts?

"The muddiest point helped me realize what I may not be aware of"

Did discussing Muddy Point(s) at start of next class help your understanding (or not)?

"Questions other people asked certainly helped because, many times they were questions I didn't think to ask"

Learning Point: Did responses help you think and monitor your learning?

"It allowed me to see the value in working in groups"

Figure 5. Final Reflection on Reflections or "Meta-Reflection" at course end with student comments.

An Overall Summary of Classroom Materials and Activities is now briefly described since refinement and remodeling materials continues, including major changes described above. Here, a given activity or material is illustrated with an example to clarify its nature and usage.

Materials and activities were refined and remodeled where there was need to improve the relationships between macroscopic properties and processing and micro and nano-level features. Materials and activities were also modified to further address students' prior knowledge, misconceptions, and difficult concepts. The dual goals were to both characterize students' prior knowledge and misconceptions and then to use that knowledge to inform teaching and materials. As such, materials and activities are described and illustrated with examples here.

1. Teaching Methods and Interventions Throughout instruction on all topics, students were asked to frequently express their mental models in multiple modes. Student expressions and explanations of thinking took place in different ways, or representations, including written, verbal, diagrammatical, mathematical, graphical and, kinesthetic. Student written expressions resulted from in-class activities in which students worked through scenarios of usage and applications of materials in real-world items by writing down thoughts, solutions, or recommendations. Verbal expressions were enhanced by inclusion of inquiry questions during team based activities. By having students explain their ideas in various modes at various times throughout course of instruction, frequent multimodal expressions of student mental models were explored. This also promotes a richer, more complete, and holistic understanding of concepts through "triangulation" with multiple modes of expression. Additionally, Daily Reflection Points are now requested about 10 – 15 minutes prior to the end of a given class. This promotes reinforcement of that class's learning through recall and summarizing and framing of a given day's classroom experience.

2. Concept-Context Mini-Lecture Materials. The class notes were contextualized and utilized multiple representations including visual, written, graphical, and mathematical modes of explanations of content. The mini-lecture notes acted as a framework for the class. In the Fall 2011 semester 73% of the class felt that the mini-lectures supported their learning. The contextualization allowed for the instructor to interact with students and to create connections between student prior experience and new information. This interaction, and the conversation that resulted, verbally elicited student mental models. The overall structure of a topic is introduced with the homework Preview Problem Concept Map Quiz. These types of approaches were used throughout the course and addressed all eight of the Materials Course Issues.

3. Hands-on Activities for kinesthetic learning provide an opportunity to tie real-world materials and their macroscopic properties and behavior to conceptual understanding of underlying materials atomic and microscopic structure that controls macroscopic properties. In the Fall 2011 semester 92% of the class felt that the hand-on activities supported their learning. Macroscopic mechanical properties for metals, polymers and ceramics were illustrated with objects that included paper clips, grocery bags, and chalk. Student observations are linked to mini-lecture content, although there is a need to create worksheets so students can record their observations and link them to content. Students respond very well to hands-on activities, with one student even commenting on the plastic bag deformation activity, shown in Figure 6, that, *"Breaking stuff increases knowledge. Stretching things stretches your mind."*

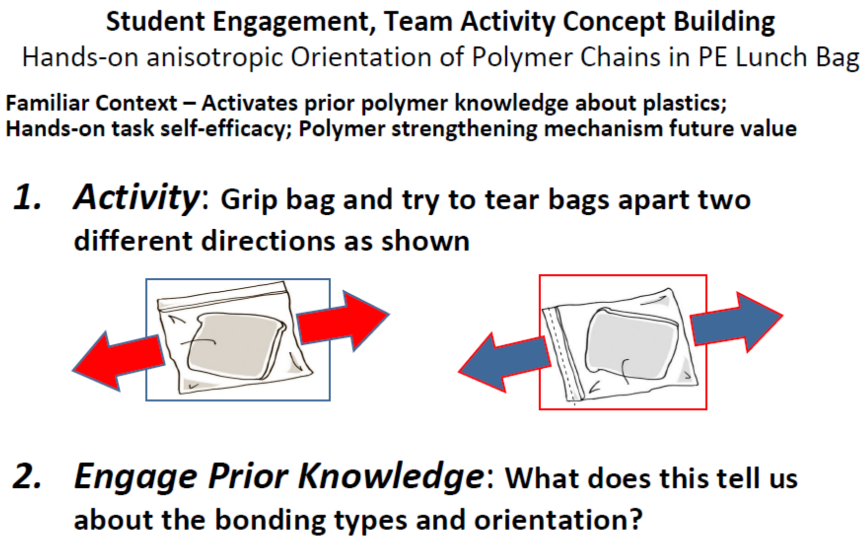


Figure 6. Kinesthetic activity of examining orientation effects in a polymer bag.

4. Concept-Context Maps are used to actively engage students in constructing vocabulary or concepts delineated in the Preview Problem Concept Map Quiz homework. These now more effectively facilitate students' construction of a conceptual framework for topical content in a given area. They help map out content, show connections, and help define terminology, as well as illustrate familiar contexts for abstract concepts that are used in a topical area. In static form Concept Maps were quite popular with students to help follow and clarify mini-lecture materials during class. For a class during Fall of 2010, 100% of students felt that Concept Maps supported their learning. Now, however, all maps have been modified during the third year into homework Preview Problems by making a number of "bubbles" containing concepts or information for which their content removed and incorporated into a "word bank": of 10 to 15 terms. This then becomes a so-called homework Preview Problem Quiz. When used as a Concept Map Preview Problem just 55% of the students felt it supported their learning. This indicates that students prefer to do little if anything to help them prepare for an upcoming class. When used in the classroom as a team summary activity as a "Concept Map Class Summary Quiz" it should help reinforce students' conceptual frameworks for the content covered on a given day. Shown previously in Figure 4 is a typical Concept Map Homework Preview Problem that prepares students for the upcoming class.

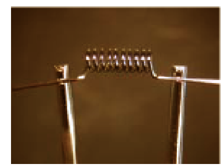
5. Concept-Context Sorting Worksheets are structured to visually bridge the concrete macroscopic properties of materials that compose real-world items and the abstract structural features of the materials that are the basis for their properties. They contextualize complex concepts and allow students to organize their ideas of a specific topic. For these worksheets, students were given “answer banks” for different technical aspects of 4-8 real-world objects or scenarios. Using the answer bank, students fill in the one appropriate answer for the particular, specific property of each object. These were used to elicited students’ abilities to interpret graphical and visual representations of phenomena. When this multimodal expression occurred, the instructor observed student graphical and visual expressions of student mental models. These are supplemented with inquiry questions to reinforce understanding of concepts underlying the activity. During the Fall 2010 term 82% of the students felt that this activity supported their learning. A typical activity, Materials Selection for a Bicycle, is shown below in Figure 7.

Class Activity: Materials Selection for Bike Components

5. Materials Selection and Properties .

Choose the most likely property, material, bonding, and process for these motorcycle items (16 pts)

	property	material	bonding	processing
i) bicycle frame	______	________	________	________
ii) headlight filament	______	________	________	________
iii) bicycle headlight lens	______	________	________	________
iv) bicycle tire	______	________	________	________



PROPERTIES	MATERIAL	BONDING	PROCESSING
I. transparent and waterproof	1. tungsten - W	A. covalent	a. vulcanization
II. stiff and ductile	2. 80% SiO_2 + 20% NaO	B. ionic	b. float on molten Sn + cut
III. rubbery and tough	3. polybutadiene rubber	C. metallic	c. wire drawing
IV. thermally stable electrical conductor	4. 1020 steel	D. van der Waals	d. extrusion
		E. covalent & van der Waals	

Figure 7. Materials selection sort-and-match activity for bicycle components

7. Visual Glossaries of Terminology were created to help students visualize the terminology of concepts, contexts, processing, testing, and properties for a given topic. A problem with traditional blackboard / lecture instruction is that students must move quickly from memorizing and applying quantitative relationships to solving representative problems. This occurs without teaching students the qualitative models that scientists and engineers use to support reasoning in their own problem solving activities. Physical and visual models help clarify scientific or engineering principles and associated explanations which may not be apparent when only verbal or mathematical representations are conveyed with words or blackboard writing. The visual qualities of a model are more easily explained and understood and integrated into a developing conceptual framework. The images of visual glossaries of terminology are more readily recalled and used by students than typical "words-only" definitions. In the third year the Visual Glossaries were extended to all topical areas. This was done due to their popularity as indicated by the result that in Fall 2011 88% of the class stated that Visual Glossaries supported their learning. Shown in Figure 8 is the first page of a Visual Glossary of Crystal Structures.

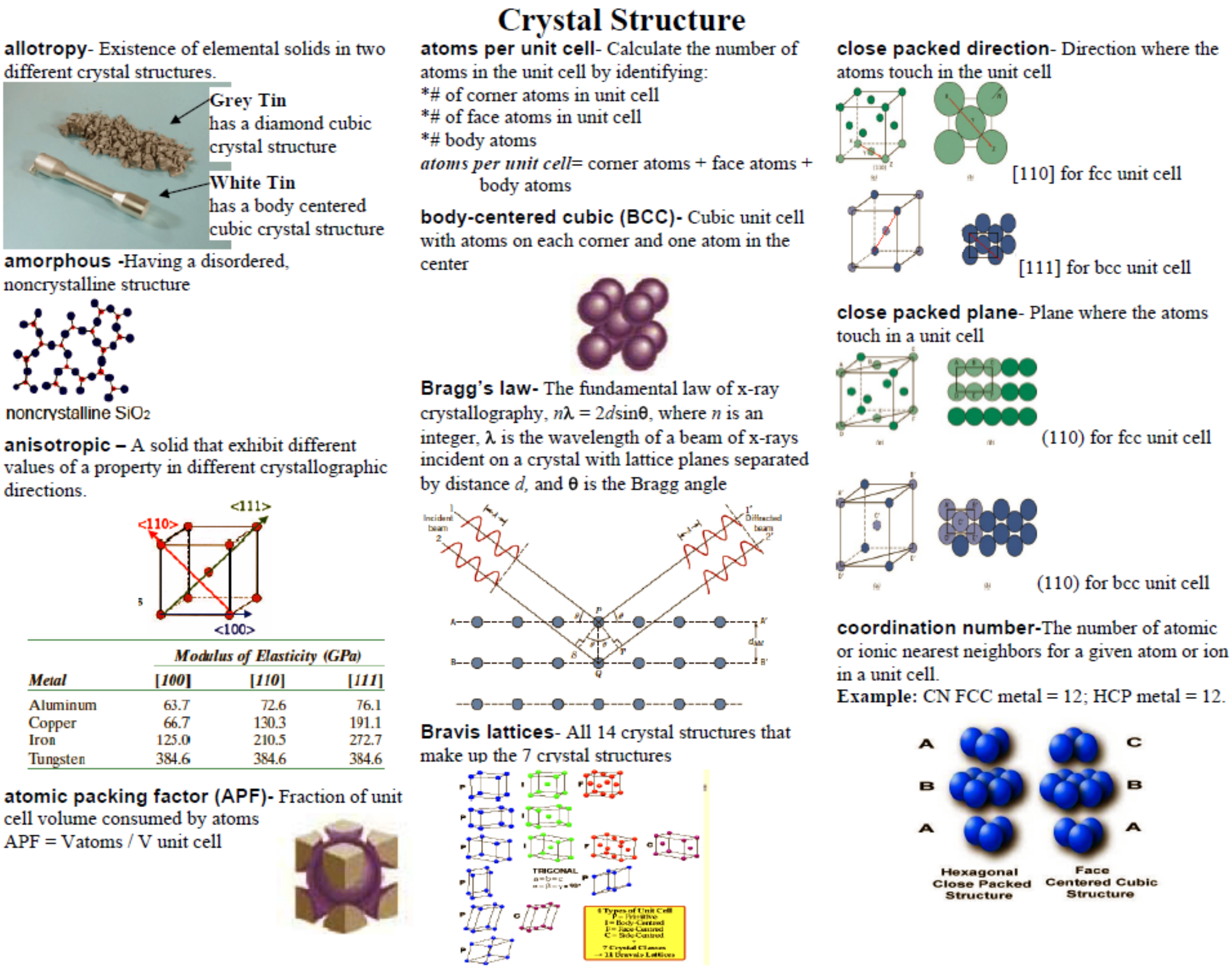


Figure 8. Visual Glossary of Crystal Structures

6. Visual Glossaries of Materials Processing are also quite popular with students. They illustrate different materials processing methods that are associated with the real-world items on the worksheet. In the discipline of materials science and engineering the interconnection of critical concepts is often illustrated by a tetrahedron which has as its vertices Structure – Processing – Properties - and Performance/Application. This demonstrates the interconnection and interdependence of the characteristics of a material and its relationship to successful performance in a technological system. Most materials textbooks have limited emphasis on the topic of materials processing, but the topic is intimately related to a materials' properties and applications. As such, activities were created that demonstrated these relationships, but students in the materials class were unfamiliar with the terminology of materials processing. This issue was successfully addressed with creation of Concept in Context Visual Glossaries of Materials Processing. These accompanied classroom activities and mini-lectures and are also used in homework problems. Students continue a positive reaction to these glossaries. A Visual Glossary of Metal Processing is shown in Figure 9.

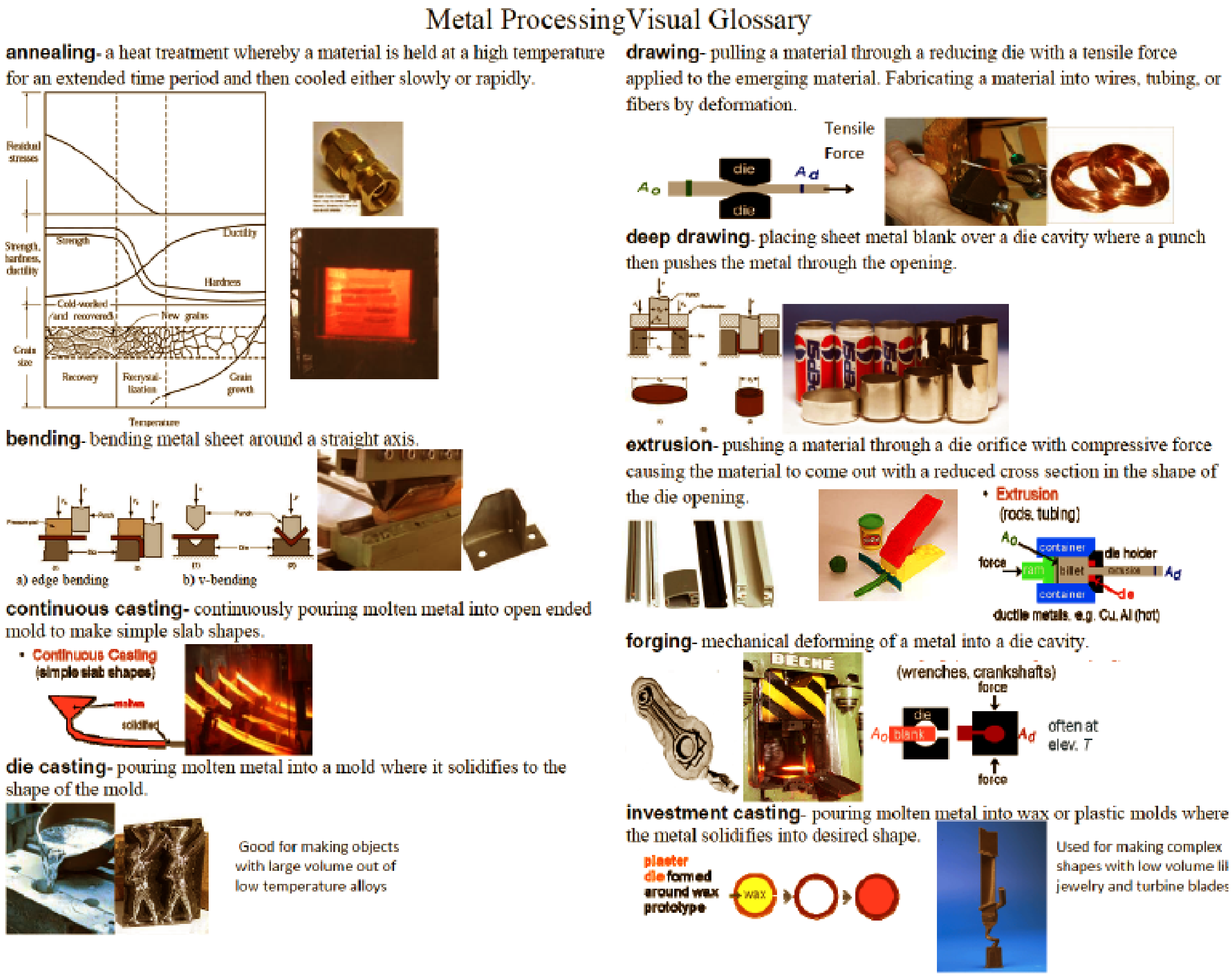
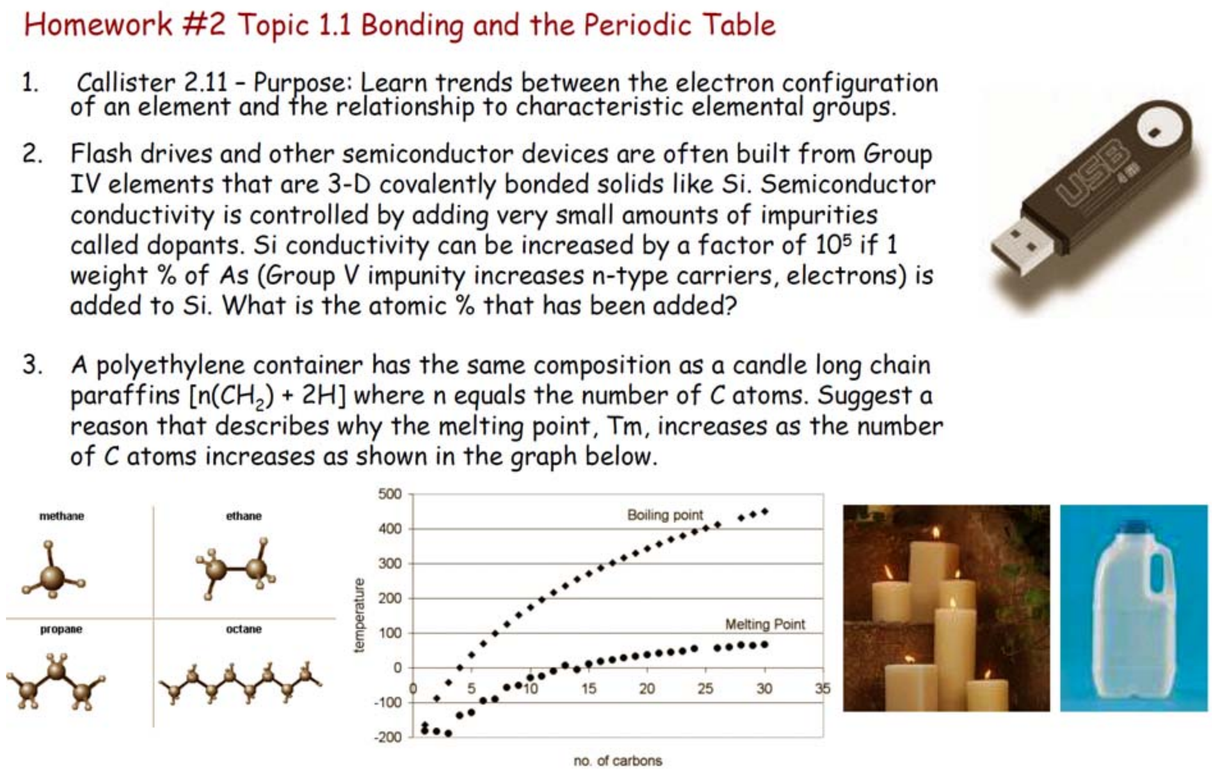


Figure 9. Visual Glossary of Metal Processing

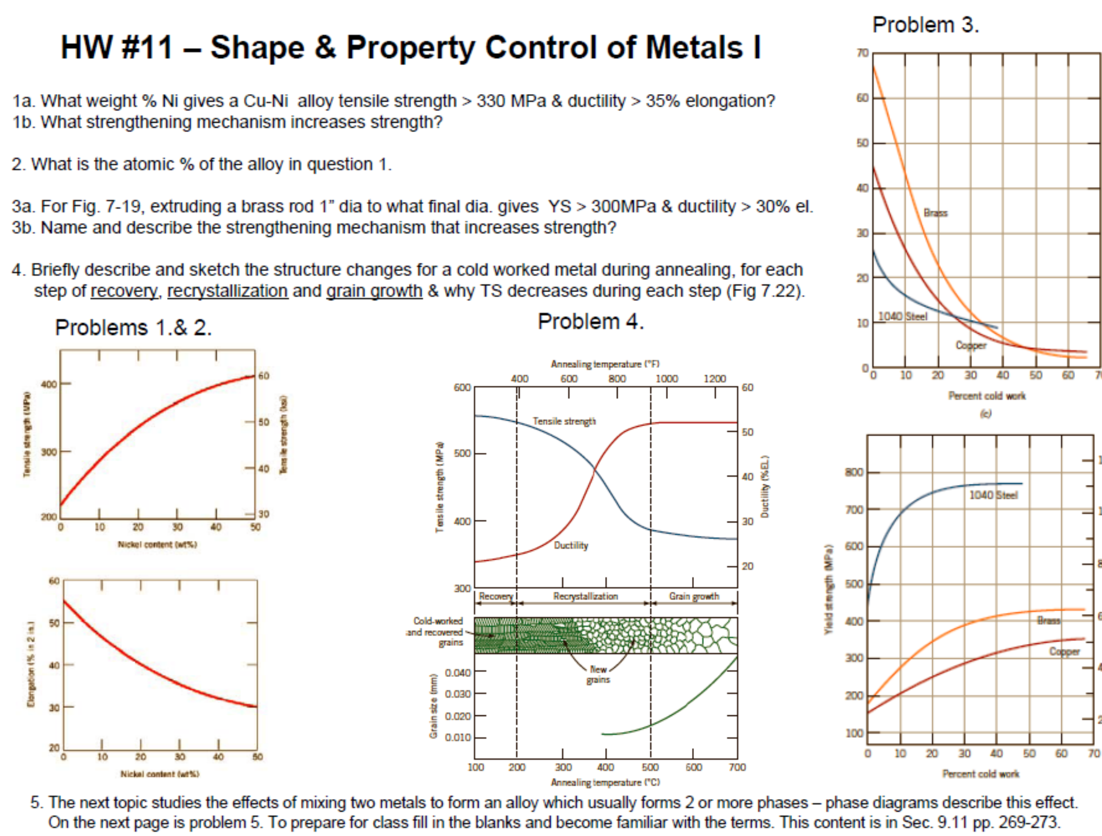
8. Homework Multimodal Contextualized Problems require students to explain phenomena in multiple modes including written, visual, graphical, and mathematical representations. By requiring this, the instructor is able to elicit student mental models in each of these different ways. Student participation in this process gives the instructor an additional opportunity to observe students express their mental models verbally, graphically, visually, and mathematically. Figure 10 shows a problem set that uses the context of a semiconductor flash memory storage drive as an application for solving a unit conversion problem that requires student to convert from a basis of weight % to atomic %. During the last year there has been a growing awareness from homework and Daily Reflections that some students lack adequate graphing skills, which may be impeding their learning. Shown in Figure 11 is a homework problem set that requires students to describe and sketch mechanisms of structural change during annealing or cold-worked metal. There are also graphing activities to strengthen graphing skills.



Homework #2 Topic 1.1 Bonding and the Periodic Table

1. Callister 2.11 – Purpose: Learn trends between the electron configuration of an element and the relationship to characteristic elemental groups.
2. Flash drives and other semiconductor devices are often built from Group IV elements that are 3-D covalently bonded solids like Si. Semiconductor conductivity is controlled by adding very small amounts of impurities called dopants. Si conductivity can be increased by a factor of 10^5 if 1 weight % of As (Group V impunity increases n-type carriers, electrons) is added to Si. What is the atomic % that has been added?
3. A polyethylene container has the same composition as a candle long chain paraffins [$n(CH_2) + 2H$] where n equals the number of C atoms. Suggest a reason that describes why the melting point, Tm, increases as the number of C atoms increases as shown in the graph below.

Figure 10. Contextualized homework problems showing application contexts related to problems.



HW #11 – Shape & Property Control of Metals I

1a. What weight % Ni gives a Cu-Ni alloy tensile strength > 330 MPa & ductility > 35% elongation?
1b. What strengthening mechanism increases strength?

2. What is the atomic % of the alloy in question 1.

3a. For Fig. 7-19, extruding a brass rod 1" dia to what final dia. gives YS > 300MPa & ductility > 30% el.
3b. Name and describe the strengthening mechanism that increases strength?

4. Briefly describe and sketch the structure changes for a cold worked metal during annealing, for each step of recovery, recrystallization and grain growth & why TS decreases during each step (Fig 7.22).

5. The next topic studies the effects of mixing two metals to form an alloy which usually forms 2 or more phases – phase diagrams describe this effect. On the next page is problem 5. To prepare for class fill in the blanks and become familiar with the terms. This content is in Sec. 9.11 pp. 269-273.

Figure 11. Homework problems using graph reading and concept sketching skills.

Exit Survey for Student Feedback

At the end of each semester an exit survey is anonymously filled out by all students with an example from the Fall 2011 course shown in Table 1. There are two sections to the survey. The first part uses student self assessment to measure the perceived effectiveness of the course teaching strategies in terms of supporting student learning. A number of results have been previously cited with respect to the impact of classroom activities. A few highlights from the Fall 2011 survey in Table 1 showed 80% to 90% of students felt their learning was supported by teaching strategies of team-based problem solving, discussions, and hands-on activities. Affective factor results from the Personal Impact section found that the percentage of students who agreed was: 1) 65% who felt instructional strategies in the course were more motivating than those in other classes; 2) 77% felt material learned will be of value to them after graduation in career or grad school; 3) 92% felt the course helped them see the relevance of engineering to real-world needs; and 4) 67% would recommend the course to a friend. These strongly positive changes demonstrate the impact the remodeling materials and teaching with constructivist engagement principles can have on student attitude, learning, and retention.

Student Evaluation of Instructional Strategies & Impact - MSE 250, Fall 11: **250 Personal ID #______________ M F Date_________**

For each strategy below, please rate it based on its **support for student learning** (with an **X** in box).

A score of ***1*** *indicates* ***not at all supportive*** *of learning* (or ***strongly disagree***) A score of ***5*** *indicates a* ***very supportive*** *of learning* (or ***strongly agree***)	Not at All Supportive 1	Not Supportive 2	Neutral 3	Supportive 4	Very Supportive 5	4 + 5
A. Instructional Strategies						
Team based problem solving and discussions	0%	4%	12%	27%	58%	85%
Team report-out of solution to activity	4%	8%	12%	42%	35%	77%
Hands-on classroom activities	0%	4%	4%	39%	54%	93%
Contextualized Mini-Lectures Daily	8%	0%	19%	42%	31%	73%
Pre and post topic concept question sets	0%	15%	23%	27%	31%	58%
Daily Reflections – Most Interesting Point	8%	19%	46%	19%	11%	30%
Daily Reflections –Muddiest Point	4%	8%	35%	27%	23%	50%
Daily Reflections – Learning Point	12%	19%	39%	19%	8%	27%
Class Start Discussion of Prior Class Muddiest Point	0%	8%	19%	42%	31%	73%
HW Preview Problem as preparation for upcoming class	12%	0%	23%	38%	27%	65%
Undergraduate teaching assistant working with teams	0%	4%	15%	31%	50%	81%
Visual glossaries of terminology	0%	4%	4%	42%	46%	88%
B. Personal Impact of This MSE 250 Class on Student	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	
This class increased my interest in continuing in my engineering major	4%	0%	8%	46%	42%	88%
Because of 250 I would consider taking more classes in materials engineering	4%	8%	31%	19%	39%	58%
Material I learned will be of value to me after graduation in career or grad school	0%	0%	23%	46%	31%	77%
Instructional strategies in 250 were more motivating than those in other classes	12%	0%	23%	27%	38%	65%
This course helped me see the relevance of engineering to real-world needs	0%	0%	8%	42%	50%	92%
I would like to see MSE 250 instructional strategies used in other courses	4%	12%	4%	39%	42%	81%
I would recommend this course to a friend	8%	4%	4%	42%	42%	84%

1) Most effective strategies for learning - A. Team prob. solving & discussion **(20)** B. Team report out **(2)** C. Hands-on activities **(15)** D. Contextual mini-lectures **(3)**
(circle top 3 choices)
E. Interesting Pt.**(0)** F. Muddiest Pt. **(1)** G. Learning Pt **(0)** H. Muddiest Pt. Discussion **(6)** I. HW Preview Problem **(3)** J. Undergrad TA **(7)** K. Visual Glossaries **(7)**

Table 1. Fall 2011 Introductory Materials Course Exit Survey on Student Evaluating of Instructional Strategies and Personal Impact of Learning

Discussion and Conclusions

Addressing Materials Course Instructional Issues

At the beginning of this paper a series of Materials Course Instructional Issues and Impact were highlighted to demonstrate the need for remodeling course instruction, materials and assessments. Approaches were devised baser on the principles of the book How People Learn. We will now discuss approaches that were used for each issue.

1. *Connecting macro-properties & micro-structure relationships at different length scales.* To better help students connect their own experience with abstract concepts presented in the course contextualized lecture slides, classroom activities, and homework problems were developed. The Exit Instructional Strategies Survey showed that 65% to 93% of students felt that such strategies supported their learning.

2. *Uncovering and repairing misconceptions and filling in knowledge gaps of materials concepts.* Assessments at three time scales (semester, topic, and class) provided much information both about student knowledge as well as about students' personal learning and knowledge issues. The usefulness of this strategy is reflected by student attitude that showed that 73% stated that Muddiest Point Commentary supported their learning.

3. *Large body of terminology > 400 new terms & > 100 new symbols & units.* This issue was addressed with a series of Visual Glossaries for all class topics and also Concept Map Preview Problems for every class which helped students learn vocabulary and terminology as well as familiarizing them with the conceptual framework of a given topic or sub-topic. This is shown by the fact that students said their learning was supported at a level of 88% for Visual Glossaries and at a level of 65% for Concept Map Homework Preview Problems.

4. *Lack of class activities in materials texts for engaging students in their own learning*. One or more activities have been created for all of the 24 classes in the course. Students reported quite positive attitudes about activities and felt their learning was well supported with survey values of 75% to 93% for team based activities, discussions and report outs.

5. *Lack of contextualization in materials texts which could help students see the value of abstract concepts when related to concrete engineering items*. All classes mini-lecture, activities, and homework had contextualized content. Students felt quite positive about contextualization as seen in the Personal Impact Survey for which students agreed at a level of 92% that *"This course helped me see the relevance of engineering to real-world needs"* and at a level of 77% that *"Material I learned will be of value to me after graduation in career or grad school."*

6. *Preparation-challenged students who rarely read the text due to its volume and lack of context*. Students felt that class preparation strategies supported their learning at a level of 88% for Visual Glossaries and at a level of 65% for Concept Map Homework Preview Problems.

7. *Decreasing class attendance across a semester due to lack of student engagement perception of low value of lecture content that is similar to book and lack of awareness of student issues*. Class attendance usually varies between 80% - 90% throughout the whole semester when student engagement strategies are used while three other sections have attendance that varies between 50% to 60% for classes at the end of a semester. This is reflected by a few items in the Personal Impact

Section for which students agree at a level of 65% that "*Instructional strategies in 250 were more motivating than those in other classes*", 81% that "*I would like to see MSE 250 instructional strategies used in other courses*" and 84% would "*recommend the course to a friend*".

8. *Withdrawal of students from materials classes due to loss of value and interest in class*. Figure 12 shows the persistence rate in for lecture versus engagement pedagogies for classes taught by the same instructor with values of 85% persistence for lecture versus 95% persistence for engagement. Additionally, persistence of women increased from 60% for lecture versus 90% for engagement pedagogy. Factors that improve persistence are likely similar to those for attendance as discussed above. An important additional factor for long term persistence beyond the materials class is that 88% of students were in agreement with the fact that "*This class increased my interest in continuing in my engineering major*." This suggests that the content, teaching strategies, and relevance of the materials course may improve students' perspective on the engineering discipline as a whole.

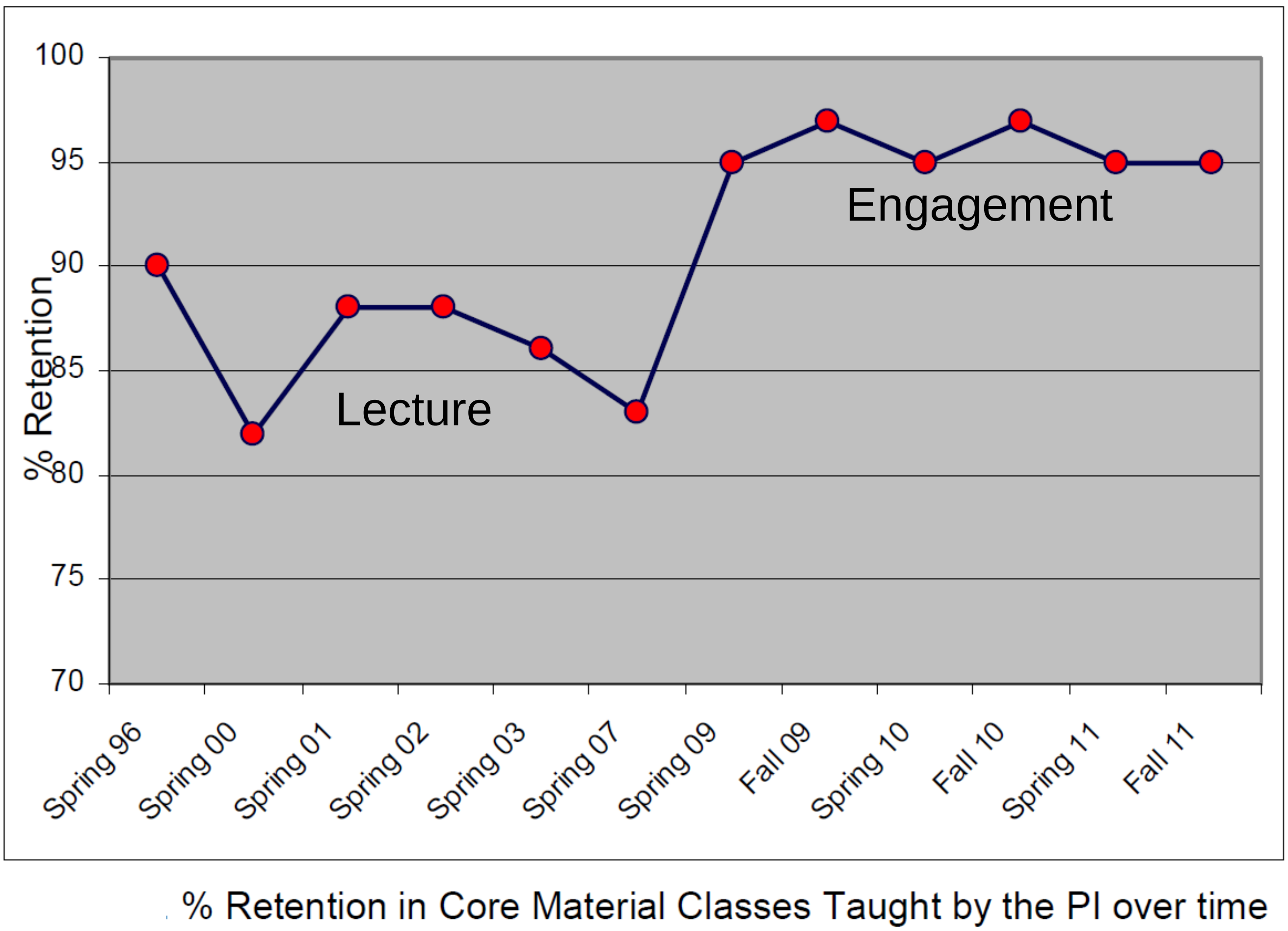


Figure 12. Effect of Lecture vs. Engagement Pedagogy on Persistence in a core materials class.

In this paper we have described a number of strategies to address instructional issues in a core materials class. As a result of these strategies new instructional content, materials and assessments were created. As a result of these improvements it has been shown that students who are learning by actively engaging with one another with content that shows real-world applications of principles are impacted in important ways. These include the following. Comparing an active learning class to a lecture-based class average conceptual gain (measured by the Materials Concept Inventory) increased from 18% to 42%; increased class persistence from 85% to 95%; and decreased female withdrawal rate from 40% to 10%. In team engagement it was shown that 80% to 90% of students felt their learning was supported by teaching strategies of team-based problem solving, discussions, and hands-on activities. Affective factor results found that the percentage of students who agreed was: 1) 77% felt material learned will be of value to them after graduation in career or grad school; 2) 92% felt the course helped them see the relevance of engineering to real-world needs; and 3) 67% would recommend the course to a friend. These strongly positive changes demonstrate the impact the remodeling materials and teaching with constructivist engagement principles can have on student attitude, learning, and retention.

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