Effect of Contextualization of Content and Concepts on Students' Course Relevance and Value in Introductory Materials Classes

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Stephen Krause is professor in the Materials Science Program in the Fulton School of Engineering at Arizona State University. He teaches in the areas of introductory materials engineering, polymers and composites, and capstone design. His research interests include evaluating conceptual knowledge, misconceptions and technologies to promote conceptual change. He has co-developed a Materials Concept Inventory and a Chemistry Concept Inventory for assessing conceptual knowledge and change for introductory materials science and chemistry classes. He is currently conducting research on NSF projects in two areas. One is studying how strategies of engagement and feedback with support from internet tools and resources affect conceptual change and associated impact on students' attitude, achievement, and persistence. The other is on the factors that promote persistence and success in retention of undergraduate students in engineering. He was a coauthor for best paper award in the Journal of Engineering Education in 2013.

Dr. Cindy Waters, North Carolina A&T State University

Her research team is skilled matching these newer manufacturing techniques to distinct material choices and the unique materials combination for specific applications. She is also renowned for her work in the Engineering Education realm working with faculty motivation for change and re-design of Material Science courses for more active pedagogies

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BIOGRAPHICAL SKETCH

Professor Joe Stuart

PROFESSIONAL PREPARATION

B.Sc., Metallurgical/Mechanical Engineering, University of Nevada at Reno (1969) M.Sc., Physical Science, University of Southampton, UK (1972)

APPOINTMENTS

2006 to Present Program Director Manufacturing Engineering Technology, OIT 2011 to Present Associate Professor, MMET Department, Oregon Institute of Technology 2004 to 2011 Assistant Professor, Oregon Institute of Technology, Klamath Falls 2002 to 2004 National Accounts Manager, Wagner Electronics 1998 to 2002 President/Owner, Best Tech USA 1985 to 1998 VP and General Manager, Alumaweld Boats Inc & Rogue Trailers Inc. 1984 to 1985 Manufacturing Rep MDA Associates 1981 to 1984 Quality Engineer, International Memories Inc. 1980 to 1981 Design Engineer Balteau Standard 1977 to 1980 Field Engineer, Wisar Construction 1975 to 1977 General Manager Milthorn Toleman Ltd., UK 1974 to 1975 Chief Scientist, Puerto Rico Nuclear Center 1972 to 1974 Engineering Consultant, EPA 1969 to 1970 Metallurgical Engineer, Republic Steel Inc.

Professional Societies:

American Society of Engineering Education, Life time member Society of Manufacturing Engineering, American Society of Mechanical Engineers

PUBLICATIONS

(i)Most Closely Related [1] W.J. Stuart 'Problem Based Case Learning - Composite Materials Course Development – Examples and classroom reflections' NEW Conference, Oct 2011 [2] W.J. Stuart and Bedard R. (EPRI) 'Ocean Renewable Energy Course Evolution and Status' presented at Energy Ocean Pacific & Oregon Wave Energy Trust Conference, Sept. 2010. [3] W.J. Stuart, Wave energy 101, presented at Oregon Wave Energy Symposium, Newport, OR, Sept. 2009. [4] W.J. Stuart, Corrosion considerations when

designing with exotic metals and advanced composites, presented at Corrosion Conference of Exotic Metals, Park City, UT, 2009. [5] W.J. Stuart, Ruth Loring, Ed Webster, Frank Cox, Composite materials course development using problem based case learning techniques, National Educators Workshop, Greensboro, NC, 2009. [6] W.J. Stuart, Three pronged approach to sustainability at OIT, presented to faculty and staff at OIT 2008 Fall Convocation, 2008. [7] W.J. Stuart, Sustainability workshop, presented to faculty and staff at OIT 2006 Fall Convocation, 2006. (ii) Other [1] W.J. Stuart, Successful programs that have been enriched by industry and engineering education connections, Proceedings of ASEE Conference, Chicago, IL, 2006.

SYNERGISTIC ACTIVITIES

• Course development for Ocean Renewable Energy for Manufacturing Engineering Technology and Renewable Energy Engineering students: developed and taught a new undergraduate dual listed course, Ocean Renewable Energy, in spring 2010. This course has now also been developed and is offered (and has been taught) as a 'Distance Education' course. • Course and lab development for Advanced Composites for Manufacturing Engineering Technology and Mechanical Engineering Technology students: developed and taught a new undergraduate dual listed course, Advanced Composites, in spring 2009 and winter 2010. • Student advising and course integration in sustainable concepts and life cycle analysis and material selection considerations. • Innovations in teaching: used innovative teaching methods to enhance the learning experience through introducing problem based case learning techniques in classes and course structure; presentation of paper in National Educators Workshop.

COLLABORATORS AND OTHER AFFILIATIONS

(i) Collaborators and Co-Editors Frank Cox, Edmonds Community College; Ruth M. Loring, Nashville State Community College; Wangping Sun, Oregon Institute of Technology; Ed Webster, Institute for Professional Training and Education; John Anderson, Oregon Institute of Technology

(ii) Special Material Expert Curriculum development for National Resource Center-CAM composite materials course for National Resource Center at Edmonds Community College.

Dr. Eugene Judson, Arizona State University

Eugene Judson is an Associate Professor of for the Mary Lou Fulton Teachers College at Arizona State University. His past experiences include having been a middle school science teacher, Director of Academic and Instructional Support for the Arizona Department of Education, a research scientist for the Center for Research on Education in Science, Mathematics, Engineering and Technology (CRESMET), and an evaluator for several NSF projects. His first research strand concentrates on the relationship between educational policy and STEM education. His second research strand focuses on studying STEM classroom interactions and subsequent effects on student understanding. He is a co-developer of the Reformed Teaching Observation Protocol (RTOP) and his work has been cited more than 1500 times and his publications have been published in multiple peer-reviewed journals such as Science Education and the Journal of Research in Science Teaching.

Dr. Casey Jane Ankeny, Arizona State University

Casey J. Ankeny, PhD is lecturer in the School of Biological and Health Systems Engineering at Arizona State University. Casey received her bachelor's degree in Biomedical Engineering from the University of Virginia in 2006 and her doctorate degree in Biomedical Engineering from Georgia Institute of Technology and Emory University in 2012 where she studied the role of shear stress in aortic valve disease. Currently, she is investigating cyber-based student engagement strategies in flipped and traditional biomedical engineering courses. She aspires to understand and improve student attitude, achievement, and persistence in student-centered courses.

Ms. Bethany B. Smith, Arizona State University

Bethany Smith is currently a master's student in materials science and engineering at Arizona State University. She has been involved in STEM education research since 2012 under the direction of Professor

Stephen Krause. Her research interests in STEM education include faculty development, best classroom practices, and improving undergraduate engineering student retention through understanding what makes students leave engineering. She will be pursuing her PhD in Materials Science and Engineering starting in 2016 at the University of California Berkeley.

Effect of Contextualization of Content and Concepts on Students' Course Relevance and Value in Introductory Materials Classes

Contextualization of a course's content and concepts can improve student motivation, learning, and persistence. In this research eight faculty at four institutions implemented web-enabled, engagement and feedback pedagogy in an NSF TUES Type 2 project, JTF (Just-in-Time-Teaching with Interactive Frequent Formative Feedback). A key feature of the pedagogy is contextualization of content and concepts in introductory materials science courses. The theoretical framework used to structure the research is based on principles described in the book How People Learn. The book discusses how cognitive processes act to achieve learning through conceptual change based on three major principles, which include the following. For more effective learning, instructors need to: 1) identify students' prior knowledge to inform instruction; 2) engage students to promote conceptual change so they can construct deep knowledge organized in a conceptual framework; and 3) encourage metacognition to build habits of expert learners who define their learning goals and monitor their own progress. The research question is, "What is the role and impact of contextualization of content with respect to student attitude, achievement and persistence."

The use of contextualization of content is supported by the three principles. For the first principle, prior knowledge, it has been shown that instruction with contextualized content can activate learners' prior knowledge and promote more effective problem solving. One student said in a reflection, "Relating things to my daily life helped me to retain information better." For the second principle, promoting conceptual change, contextualization of content in interactive classroom engagement activities that motivates students with a concept's relevance can improve learning. One example was a video on precipitation of a supersaturated solution, which improved student learning in a concept quiz on solutions and solubility, from Hake gain of 33% without a video to 81% when a video was included. For the third principle, promoting metacognition, contextualization of content helps students reflect on their learning to bridge ideas from a familiar concrete context of an abstract concept so they can recognize their own personal relationship to these concepts. One student said in a reflection, "Helped me reflect on what I enjoyed and understood well from the lecture." The students' motivation for using contextualized content is well supported by a Spring 2016 semester beginning survey on Student Classroom Motivation Survey for using real world applications related to content and concepts. The survey consisted of 24 statements based on Expectancy Value Theory on a scale of 1, strongly disagree, to 4, strongly agree. Students agreed or strongly agreed with almost all statements with the following values; 2.58 for expectancy (expectation to succeed); 3.16 for value (of contextualization); and 2.12 for (cost of using contextualization). These values support questions from another exit survey on Support of Student Learning Strategies from Spring 2014. For the strategy of using contextualized hands-on classroom activities, 91% said it supported or strongly supported their learning. For contextualized mini-lecture, 79% said it supported or strongly supported their learning. Finally, for the statement, "Material I learned in this class will be of value to me after graduation in career or graduate school," 86% agreed or strongly agreed. Overall, the key feature of contextualization of content in the web-enabled, engagement and feedback pedagogy in the JTF project played an important role in enhancing student attitude, achievement, and persistence.

Introduction

The science of learning is moving forward rapidly, as described in *How People Learn (HPL)*: *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. Contextualization to connect students' prior conceptual knowledge in class can help activate that knowledge and promote learning[2]. A second principle is 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[3, 4]. Contextualization of content in interactive classroom engagement activities can motivate students with a concept's relevance that can improve learning. 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[5]. Contextualization of content helps students reflect on their learning to bridge ideas from a concrete context of an abstract concept so they can recognize their own relationship to these concepts, contexts, and their technical future. The findings help guide engineering education research to develop innovative strategies in teaching and learning to enhance students' knowledge, skills, and understanding. We will use these three principles from How People Learn (HPL) to relate how contextualization of course materials resulted in more effective learning. As such, the research question here is, "What is the role and impact of contextualization of content with respect to student attitude, achievement and persistence."

Background

In the JTF (Just-in-Time-Teaching with Interactive Frequent Formative Feedback) project there is a collaboration between faculty at: Arizona State University, a large public university, North Carolina A and T, a medium size, historically black university; Oregon Institute of Technology, a medium size technology institute; and Oregon State University, a medium size, west coast university. From this collaboration, a JTF community of practice has developed through monthly web meetings, workshops, and web communications. Ongoing discussions on topics of barriers, benefits and community resources in implementing JTF web-enabled, engagement and feedback pedagogy are showing progress. An important component of the pedagogy is contextualization of classroom content. More experience in using the pedagogy and increasing availability of new web resources, such as Blackboard or Concept Warehouse for automated Muddiest Point data collection, is now facilitating greater use of JTF resources

Issues and Challenges in Introductory Materials Courses

The three HPL research-based principles have been used to contextualize the introductory materials courses through modifying and creating new contextualized content, creating contextualized activities, and promoting metacognition by linking concepts, context and skills for more effective learning. However, to better implement these principles within the framework of the introductory materials courses, issues and challenges of teaching and learning in the course were described and contrasted with traditional lecture-based approaches to teaching. Specifically, for instructors to be more effective in introductory materials courses they must address the following Introductory Materials Course Issues (IMCIs):

- *Connecting* a real-world item's macro-properties and its micro-structure relationships at different length scales
- *Identifying pre-course knowledge* in order to contextually connect to it to activate prior knowledge as well as to repair any misconceptions identified
- *Learning and understanding* a large body of terminology of more than 400 new concepts, terms and units that can be facilitated by relevance with respect to real world applications
- *Lack of* relevant contextualized class activities in materials texts for engaging students in their own learning
- *Lack of* contextualized content in materials texts which could help students see the value of abstract concepts when related to real-world concrete engineering items
- *Unprepared* students who come to class rarely reading the text due to its complexity, volume, and lack of relevance (few real-world examples)
- *Decreasing* attendance across a semester because of perceived lack of value of lecture content which has, similar to book, lack of relevance, and lack of awareness of student learning issues
- *Withdrawal* of students from materials classes due to loss of motivation and lack of content relevance

When classroom and student issues are better articulated, it is possible to better align the three major HPL principles with improved contextualized class pedagogy, instructional materials, classroom management, and metacognition. Modest changes in course and classroom protocol, pedagogy, activities and student metacognition can result in enhanced motivation and achievement which are characteristic of more effective learning. Such changes will be discussed in terms of the three HPL principles.

Identifying Students Prior Knowledge

For the first HPL principle of "*identifying students prior knowledge"* – context can activate concepts from prior knowledge[2] and identifying misconceptions that can lead to adjustments in teaching that will repair them[6,7]. In an exit survey one student said, "Relating things to my daily life helped me to retain information better." In a recent survey of eight JTF faculty responded to the question, "How frequently do you contextualize activities and content for class?", the average response, on a scale of 1 to 10, was 9.3. Much of the prior knowledge was gathered by the faculty through daily end-of-class Muddiest Point feedback with automated methods on Blackboard and Concept Warehouse. The Muddiest Point feedback reveals student prior knowledge and learning issues such as content relevance, and misconceptions and knowledge and skill gaps. JTF instructors use this feedback for next class responses, to adjust instruction, and to create tutorial videos.

An example of one web resource created in the JTF project is a set of 21 Muddiest Point YouTube tutorial screencasts videos located at Google keyword: "materialsconcepts." The basis for a video’s usefulness is that it is directed toward addressing students' prior knowledge and misconceptions as "muddiest points" to which the videos provide a response, to those points. They are explained and illustrated in straightforward student speak that targets students' learning issues. Many videos utilize contextualized real-world concrete examples linked to more abstract concepts and calculations. The usefulness of the approach is demonstrated by the more than 500,000 views of the site over the past 30 years.

Classroom Engagement of Students

For the second HPL principle of "engaging students to build deep content knowledge to form conceptual frameworks", there were important changes made in content, activities, and pedagogy of the materials. The changes are described below.

One change was modifying the author's textbook slide set to link important concepts to real-world contexts and to develop and embed contextualized classroom activities that tie critical concepts to real-world contexts. Like most introductory materials texts, these books tend 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 real-world item's 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 and other topics tend for students to lose relevance and their interest. To address such issues in atomic bonding classroom *materials selection* activities were created using components of real world systems such as motorcycles or cars or bikes[7]. Students had to link a given component's properties to an appropriate material and it's associated processing and atomic bonding. For another topic, crystal structures[8], an activity was created using real world items' phase transformations that resulted in bad consequences and was called "unit cell disasters." Students had to select crystal structures associated with phase transformations from five real-world disasters. Students were strongly motivated and enthusiastic about both the atomic bonding and crystal structure activities. Such activities addressed many of the items in Introductory Materials Course Issues (IMCIs).

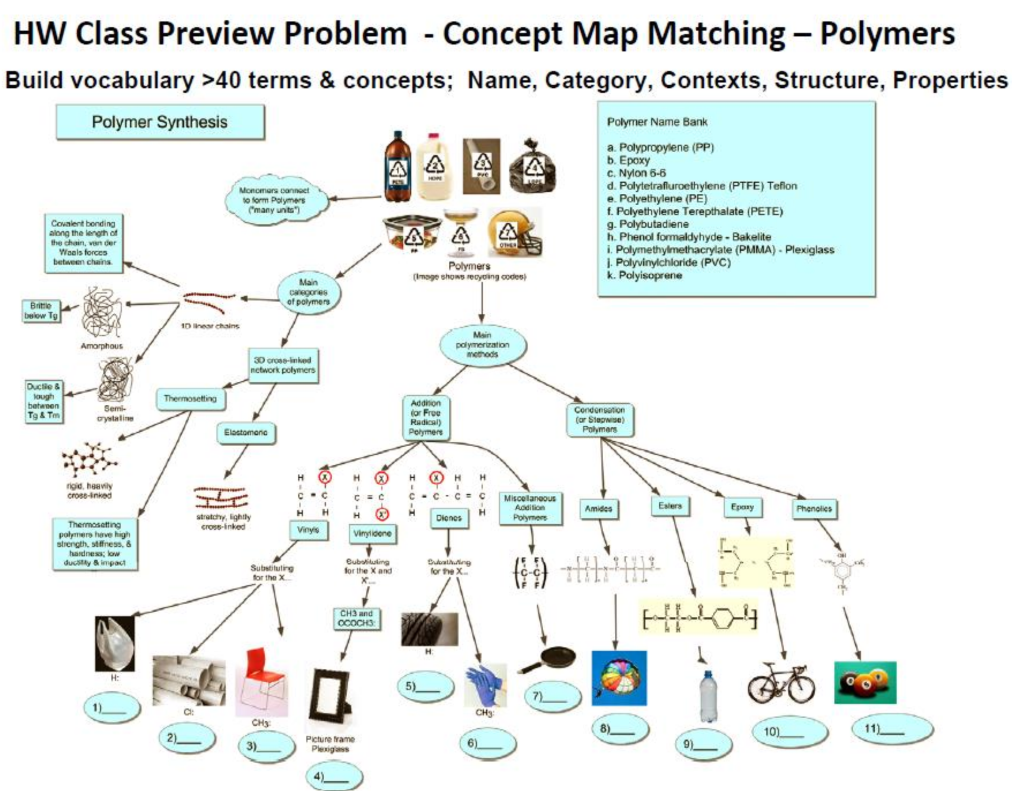

Fig. 1. Homework Preview Problem – Polymer Concept Map

Another example of contextualization of content was in the area of phase diagrams where a concept quiz indicated students could not differentiate between the concepts of a saturated and a supersaturated solution. This is a particularly important concept for the topic of age hardening of aluminum alloys where the strengthening process requires creation of a supersaturated solid solution followed by precipitation of the supersaturated phase to give strength to the alloy. After a concept pretest of solubility and saturation was given, a YouTube video was shown that demonstrated how a large amount of precipitate could come out of a supersaturated water solution once a small nucleating crystal initiated the precipitation process. When a posttest was given a few weeks later there was a dramatic increase in the posttest gain compared to previous semesters before a video had been shown. The results showed a 91% Hake gain with the video compared to the earlier 33% Hake gain without the video[9]. This result shows the value of contextualization of abstract concepts of solubility and supersaturation with the concrete example of the visual demonstration of the massive precipitation of crystals from a supersaturated solution.

Another change was development and use of contextualized Concept Map Homework Preview Problems (CMHPs)[10]. A CMHP (shown in Figure 1) is a concept map from which a set of terms or concepts or images has been removed from a level of boxes on a contextualized 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. There is a significant difference between traditional concept maps, which typically link concepts and symbols, and for Figure 1 that is the use of real-world applications of the materials whose chemical formulas are shown in the map. The CMHPs were used chiefly as prior class Homework Preview Problems but also as a team-based classroom activity. The CMHPs address many HPL principles as well as "Introductory Materials Course Issues". These are described below and illustrated with an example Concept Map Homework Preview Problem for Polymers.

- First, CMHPs 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 motivate students with contexts showing their relevance and thereby promote concept and vocabulary building to facilitate assimilation of over 400 new terms.
- Fourth, to help students prepare for the upcoming class, they use *focused reading assignments* of typically only three to six pages of reading or are linked to the next class slide set. Students won't open a book to read a 25-30 page assignment to prepare for the next class, but they might read 3 – 6 pages to solve a CMHP or look at a slide set to help them prepare for the next class.
- Fifth, some students say CMHPs are like puzzle solving.
- Sixth, as a Concept Map Homework Preview Problem, they provide a link from a given day's class topic to the next day's class topic to connect prior knowledge with new knowledge.
- Seventh, used in class team activity as a topic summary, they engage students in an enjoyable way that may contribute to course persistence in conjunction with other activities.

Encouraging Metacognition

An important factor in improving students' motivation and learning is to *encourage metacognition, "so students are motivated to develop expertise by defining learning goals and monitoring own progress.*" To encourage metacognition JTF project participants originally collected students Muddiest Points (issues of confusion or uncertainty about particular concepts or terms) on blank cards or a Muddiest Point sheet. Responses were then compiled in an Excel spreadsheet and an instructor selected four or five most frequent or difficult Muddiest Points to discuss at the beginning of the next class. This process has since been automated on Concept Warehouse web site and on Blackboard. The immediate instructor feedback from the students' Muddiest Points can address 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 discussion also links the prior class material to the new class material and helps activate previously acquired knowledge. An example of Muddiest Point feedback and the instructor response for the topic of age hardening is shown in Figures 2 and 3. The topic was contextualized with images of the 1907 Wright flyer and the contemporary Boeing 787 Dreamliner, both of which used age hardening to strengthen critical aluminum alloy components in each aircraft. Figure 2 shows the most challenging Muddiest points as selected by the instructor and Figure 3 shows instructor response to each of Muddiest Points.

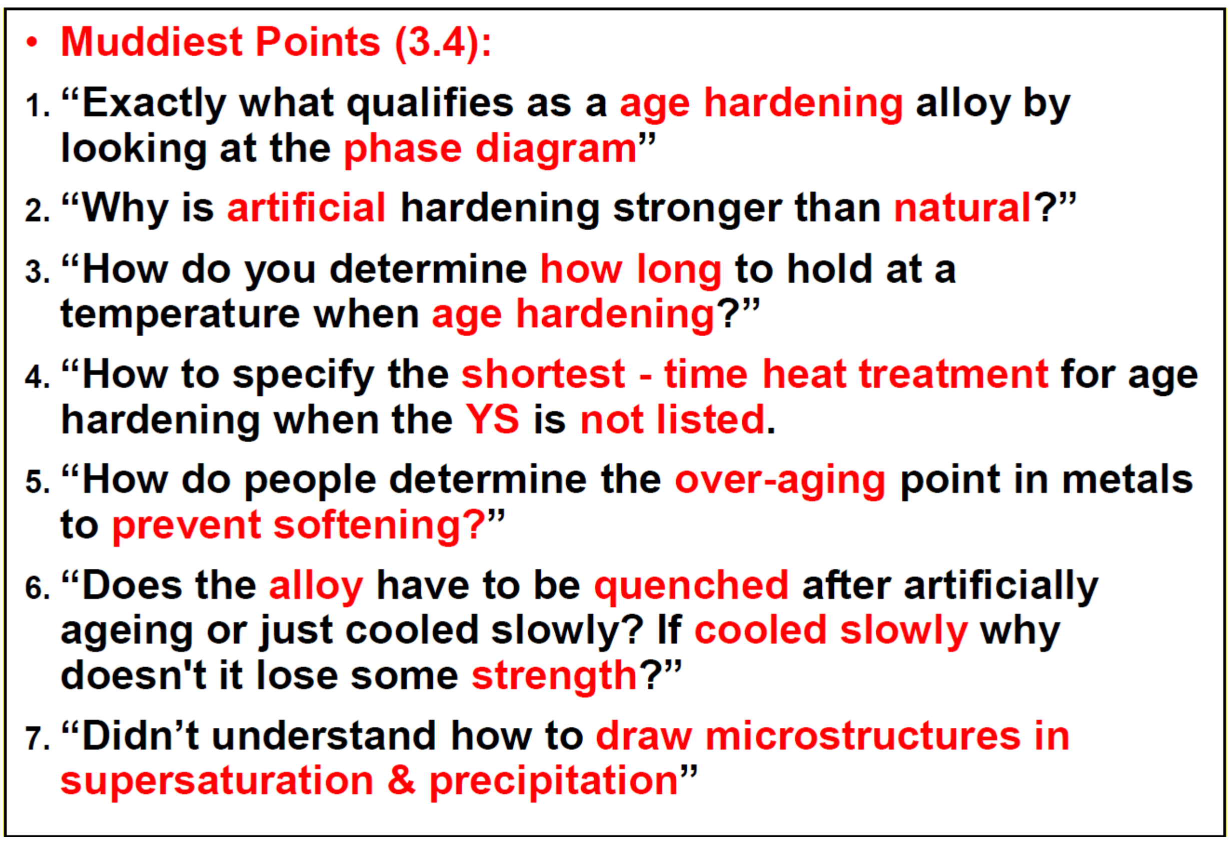

Figure 2. Summarized set of student Muddiest Point Reflections on the topic of age hardening of aluminum alloys.

These comments are authentic and in quotes, given by students in exactly the reported form, which is important, because it is better understood by students than the possible summaries or reinterpretations by an instructor. Also, the comments' intensity averaged over all Muddiest Point responses is 3.4. This is moderately muddy since near, or at, 4 is very muddy and below 3 is only slightly muddy. The instructor's synthesized white board response is shown in Figure 3, which directly addresses the issues shown in Figure 2 in a more visual and graphical way that had been taught or seen in the textbook or even a previous class mini-lecture.

With respect to the link between the student Muddiest Points in Figure 2 and the instructor response in Figure 3, there are two primary underlying issues being addressed. The first five Muddy Points relate mainly to students' lack of ability to read and interpret graphs. There also are possible associated vocabulary issues. The first comment relates to the definition and meaning of the term "supersaturated" and how to interpret it from the first two phase diagram graphs – which can possibly give a supersaturated alloy The one on the left does have a solubility limit line decreasing with temperature at both ends of the phase diagram, and supersaturation is possible. However, in the right graph there is no solid region where one element could be soluble in the other in the solid state. With no solid solubility, a supersaturated solid solution cannot be created. So the underlying reason(s) for difficulty in understanding the first explanation could lie in poor chart reading ability, vocabulary, or in the meaning of solubility limit or all. The response addresses all issues with the two graphs, but could have been improved with better labeling on the diagrams.

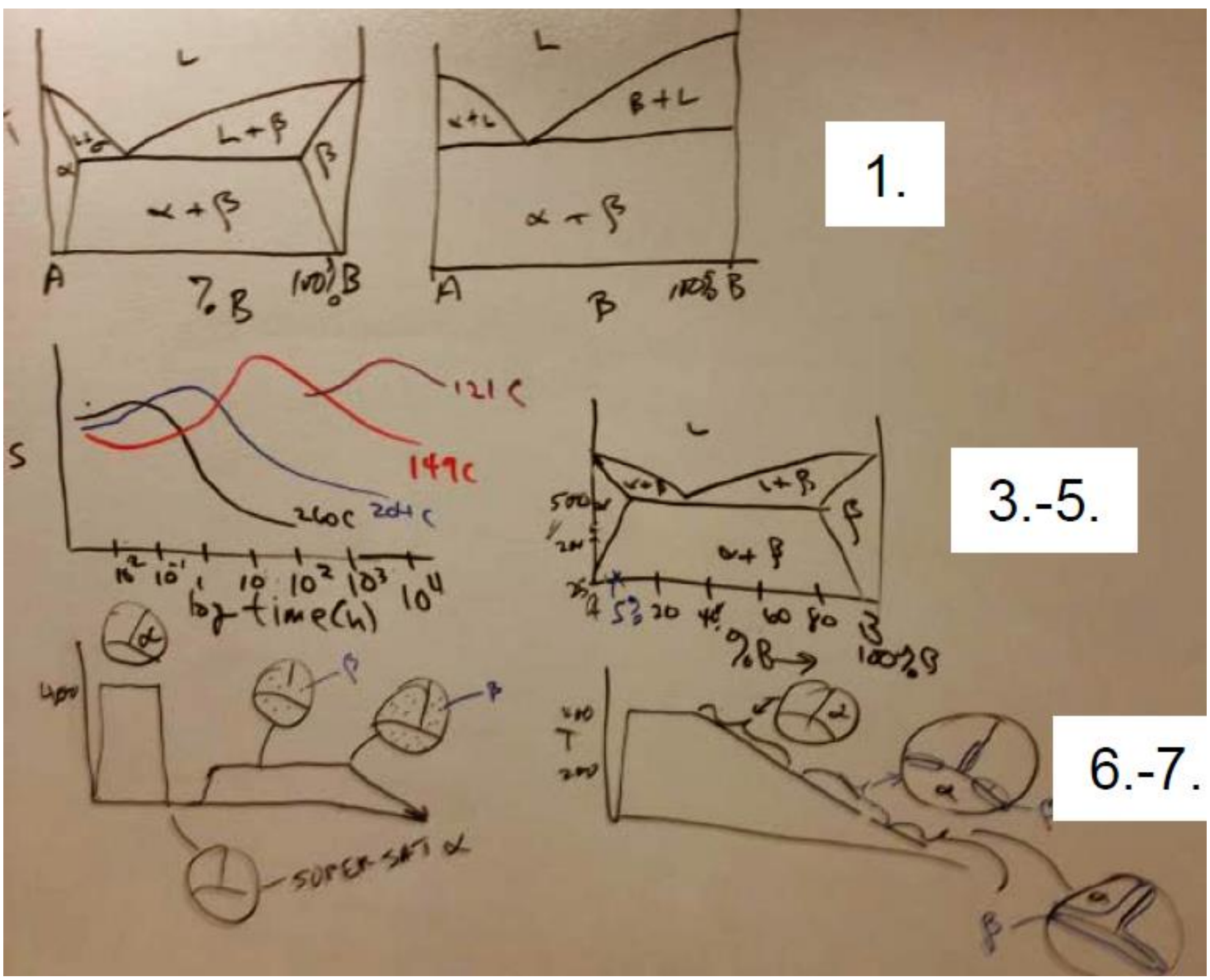

Fig. 3. Faculty response on white board to students' Muddiest Points on age hardening Al alloys.

The comments in Muddy Points 2–5 all relate to difficulty in reading the graph, which plots metal hardness (a measure of strength) as a function of annealing (elevated temperature) time on a log scale to level of hardness with four different curves representing treatment at four different temperatures. Although the graph with four curves for four temperatures was discussed and seemed to be understood, it might have been better to provide more detail of diagrams with associated microstructures for improved understanding or possibly a question-based activity could have been run for student teams to develop explanations along with report outs to the class.

Finally, the last two items have similar student learning issues related to translating graphical information to the underlying microstructure. These were addressed in the response, which made strong use of graphs and images to address misunderstandings about links between a material's microstructure and the resultant macroscopic properties. Once again, if such a problem would be encountered with traditional teaching on a homework problem or an exam, it is likely that, if a particular problem were marked wrong, it would not be explained. Instructor feedback responses address this issue. The contextualized Muddiest Point feedback challenges students to define their own learning issues, which helps clarify their knowledge and understanding. For instructors, responses challenge their pedagogical content knowledge because underlying student learning issues have been exposed and need to be addressed beyond the original delivery of the material. In the example here, the axes, graphical curves and associated microstructures were explicitly connected to hardness. Overall, visual and graphical images connected to plots and labeling key elements of images and plots helped make content more accessible to students.

Thus, student reflections can pose an interesting challenge to the instructor who may take the opportunity to help students reduce or close their knowledge gaps with his/her responses. This builds on prior knowledge of the content developed in reading text, looking at notes and slide sets, and solving homework problems. Overall, many of the "Introductory Materials Course Instructional Issues" are addressed with these student reflections and instructor feedback on the classroom contextualized content and activities.

Overall, the research question is, "What is the role and impact of contextualization of content with respect to student attitude, achievement and persistence." Student attitude was studied with an expectancy value survey on impact of contextualization on students' motivation, achievement was examined with respect to grade distribution over time progression of classes, and persistence was measured as percent of students present at the final compared to those present in the second week of class.

Results and Discussion

Student Classroom Motivation Survey for Use of Contextualized Content (SCMC)

In order to gain insight into students' attitude and motivation about the use of contextualization of content and concepts in an introductory materials course, a new assessment tool was created. It used Expectancy Value Theory[11] to assess the impact on motivational attitude of the use of relevant and contextualized examples in the introductory materials course. The survey consists of statements evaluated by students with Likert scale values ranging from 1, strongly disagree, to 2, disagree, to 3, agree, to 4, strongly agree. The statements are aligned with three components of the theory, eight statements for expectancy (E), ten statements for value (V), and six statements for cost (C). The expectancy statements are related to students' beliefs about their expectation of various factors affecting their benefit from the use of real-world contexts tied to class content and concepts. The value statements relate contextualization to three aspects of value to students, which are attainment value or importance to self, intrinsic value or interest and enjoyment, and utility value or usefulness or relevance. The cost statement relate to sacrifices that might have to be made in the use of contextualization of content and concepts in the course.

The survey in Figure 1 was given at the start of the Spring 2016 semester in an introductory materials class at a large southwestern university. There were 72 students enrolled in the class which is required by mechanical, materials, and industrial engineering, although it is an elective from students from other disciplines which included chemical and bio engineering. Students enrolled included 14 in chemical engineering, 10 in industrial engineering, 8 in materials engineering, and 40 in mechanical engineering. The levels of enrollment were 11 freshman, 15 sophomores, 17 juniors and 29 seniors. There were 55 males and 17 females enrolled.

Student Classroom Motivation Survey for Contextualization (SCMC)	**Examples of real world applications of concepts and content (averages)**
1. This strategy will not be distracting. (E)	2.32
2. I will be able to use this strategy effectively. (E)	3.2
3. Using this strategy will not make the class chaotic. (E)	2.51
4. There is an adequate amount of students in this class to implement this strategy effectively. (E)	2.35
5. Using this strategy will aid my ability to learn. (E)	3.28
6. This strategy will not be inappropriate for this subject. (E)	2.37
7. This strategy will work with my fellow classmates. (E)	2.37
8. The physical set-up of this classroom will be appropriate for using this strategy. (E)	2.24
9. Use of this strategy will not hinder my learning. (V)	2.36
10. Using this strategy will aid my career goals. (V)	3.33
11. This strategy will be a valuable instructional approach. (V)	3.33
12. Use of this strategy will help me obtain a deeper understanding of the material. (V)	3.29
13. Using this strategy will promote friendliness among my classmates. (V)	2.71
14. This strategy is aligned with the goals of my program. (V)	3.33
15. Using this strategy will help foster a positive attitude towards learning. (V)	3.19
16. This strategy will be of value to me in my future classes. (V)	3.43
17. Using this strategy will increase my comprehension and achievement. (V)	3.38
18. Using this strategy will motivate me. (V)	3.22
19. The effort involved in using this strategy will not be too great. (C)	1.98
20. It will not be difficult to use this strategy. (C)	2.22
21. Without a TA, it will be easier for me to use this strategy. (C)	1.69
22. Using this strategy will not cause me frustration. (C)	2.26
23. An appropriate amount of class time will be consumed to use this strategy. (C)	2.22
24. Using this strategy will not require too much interaction with my fellow classmates. (C)	2.35

Table 1. Student Classroom Motivation Survey for Contextualized Content & Concepts (SCMC)

The results in Table 1 for the *expectancy* component ranged from 2.24 to 3.33 with an average of 2.58. Overall, the students felt moderately positive in moderately agreeing that the factors shown would help them achieve success, or not much interfere with success, in positively benefiting from contextualization of content and concepts in the class. However, there were two factors where there was strong agreement in potential benefit of contextualization. In #2, "I will be able to use this strategy effectively", the value was 3.2. In #5, "Using this strategy will aid my ability to learn", the value was 3.28. The values of both of these statements indicate moderately strong agreement that the students have the expectation that content and concept contextualization will help lead to their success in learning the material in the course. This result emphasizes the importance of contextualization of content and concepts to students and helps promote positive attitude. The value of other expectancy factors ranged from 2.24 to 2.51, which indicate moderate agreement that the other factors that involve the students, the class atmosphere, and class layout would have a slightly positive effect, or at least would not interfere with the expectation of benefiting from contextualization of content and concepts in the class.

The results in Figure 1 for the *value* component ranged from 2.26 to 3.48 with an average of 3.16. Thus, the students felt very positive overall in moderately strongly agreeing that the value to them of contextualization of content was important for a variety of reasons. However, the area of *value for utility or usefulness* had three statements with moderately higher value average of 3.36. These statements were: 3.33 for #11 "Using this strategy will aid my career goals; 3.33 for #14 "This strategy is aligned with the goals of my program."; and 3.43 for #16 "this strategy will be of value to me in my future classes.". In the area of *attainment of learning* facilitated by contextualization of content there were four statements also with a moderately higher average of 3.29. These statements were: 3.33 for #11 "This strategy will be a valuable instructional approach."; 3.29 for #12 "Use of this strategy will help me obtain a deeper understanding of the matrial."; 3.19 for #15 "Using this strategy will help me foster a positive attitude toward learning."; and 3.38 for #17 "Using this strategy will increase my comprehension and achievement.". For the intrinsic interest and enjoyment value there is a slightly lower average of 2.97 for the two factors of: 2.71 for #14 "Using this strategy will promote friendliness among my classmates." and 3.22 for #18 "Using this strategy will motivate me.". All average results for the value of contextualization are quite positive in agreement for *value* as composed of *attainment, usefulness,* and *interest.* The motivational factor of *value* is important for self-efficacy and self-regulation that help lead to persistence and achievement, which is discussed later.The results for the *cost* component of motivation factors show modest agreement with the cost statements with an average of 2.12 for the six items. This indicates that the cost is relatively low for using the strategy of contextualization. So the cost would be relatively low for: #20 "difficulty" at 2.22; #22 "frustration" at 2.26; #23 "class time consumed" at 2.22; and #24 "too much interaction with classmates."

Overall, the survey shows that motivation of students for use of contextualized concepts as an instructional strategy is relatively strong. This is demonstrated with the very positive agreement with statements on *value*, especially for *attainment value* and *utility value.* Additionally, there is moderate agreement on statements of *expectancy* with the expectation that contextualization strategies will be successful achieving benefits. This is achieved with relatively low cost.

These results from the SCMC are also supported by the results from questions from an exit survey on Support of Student Learning Strategies from Spring 2014. For the strategy of using contextualized hands-on classroom activities, 91% said it supported or strongly supported their learning. For contextualized mini-lecture, 79% said it supported or strongly supported their learning. Finally, for the statement, "Material I learned in this class will be of value to me after graduation in career or graduate school," 86% agreed or strongly agreed.

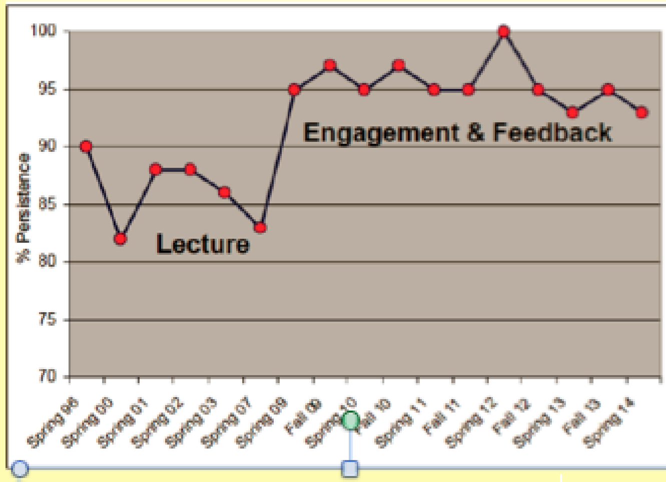

Figure 4. Class persistence – 3rd week to final

Contextualization, in conjunction with engagement and feedback, can also impact student performance in terms of class persistence and student achievement. Contextualization can have a strong positive effect on motivation, which is turn is critical for facilitating self-efficacy and self-regulated learning. Thus, context and relevance can result in students' greater belief in the potential to succeed for a topic or in a course with resultant positive impact on student persistence and achievement in the course. The overall effect of contextualization in conjunction with engagement and feedback on student class persistence is shown one *JTF* instructor's class in Fig. 4 (# students present at final exam / # students present third week), which shows improvement from average of 85% with lecture pedagogy to 95% with engagement pedagogy. For the *JTF* collaborators, persistence across collaborating universities was 97% for 227 students in four classes in Fall 2013 and 95% for 311 students in five classes in Spring 2014. These results impact one of the major concerns of engineering education, that of retention. Motivational and affective beliefs that students bring to learning contexts directly affect their persistence and effort. Two aspects of motivation will impact learning significantly. These are the degree to which students think that they are capable of completing a learning task (*self-efficacy*) and the degree to which they think that the activity is valuable to their long-term future. Students interested short-term value of their learning are more likely to use strategies that facilitate quick learning, rather than deep understanding, and will be less motivated to learn. This was also demonstrated in the results of the SCMC where student strongly agreed with the impact of contextualization on future classes, program goals and future careers.

Another measure of achievement was the change in final exam score distribution for the four instructors in the JTF project as shown in the four distributions in Figure 5. Four the four distributions for the four instructors the shift in the means over time were the following. For University 1 in Figure 5a the means shifted from 72% to 81% from 2011 to 2014. For University 2 in Figure 5b the means shifted from 68% to 77% from 2011 to 2014. For University 3 in Figure 5c the means shifted from 87% to 92% from 2012 to 2014. For University 4 in Figure 5d the means shifted from 66% to 77% from 2009 to 2013. So overall, the final grade distribution shifted from a half to a full grade point. Additionally, the percentage of Ds and Es was decreased by more than 50% overall for the four classes. This is a particularly important factor in reducing the number of students that leave engineering or leave the university and has potential to strongly impact improvements in retention.

Faculty in the *JTF* project also felt contextualization in the engagement and feedback was an important aspect of their pedagogy. As previously mentioned, faculty rated the "level of contextualization" of content in their classes as a 9.3 out of 10. This complemented their roles facilitating engagement in the classroom and helped students see the relevance and future value of the content they were learning. Some quotes from faculty about their role in the classroom included: "More of a coach than a lecturer"; "More of a guide now"; "More of a coach to encourage and guide"; and "I am a guide and they must take on the learning".

Figure 5a. University 1 - Intro to Materials

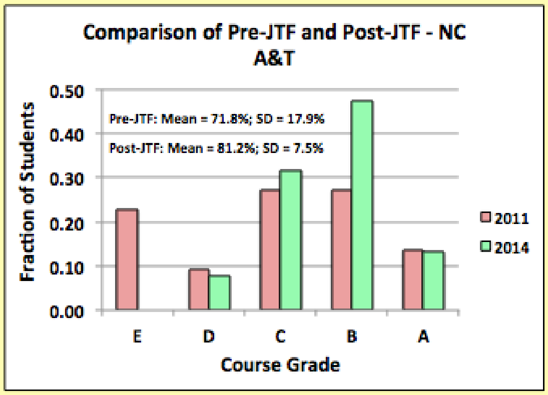

Figure 5b. University 2– Math. Methods Materials

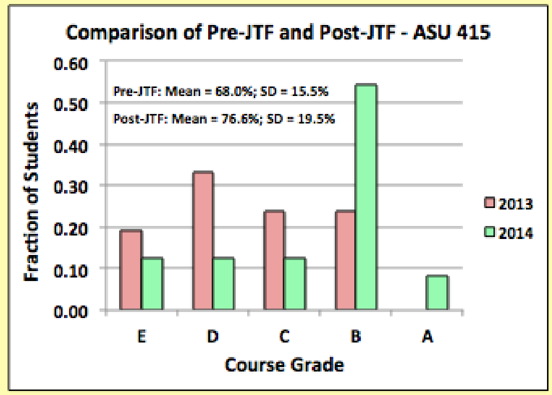

Figure 5c. University 3 – Intro Materials

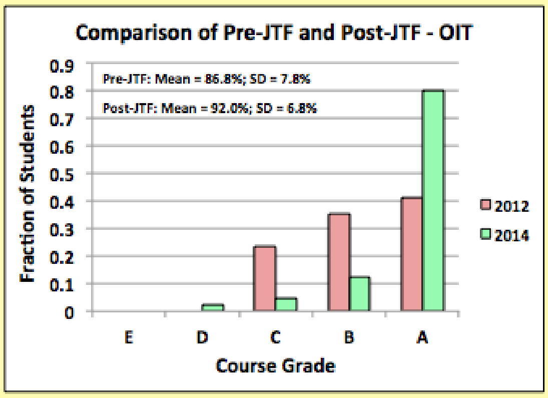

Figure 5d. University 4– Intro Materials

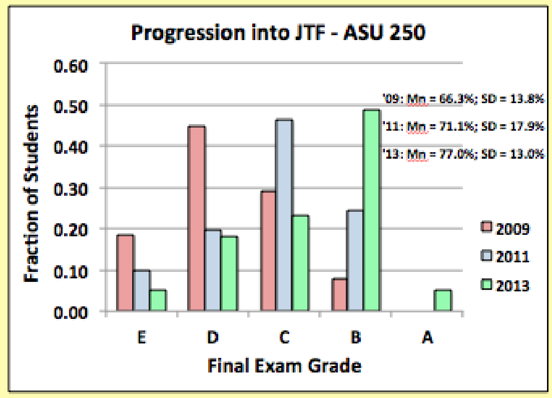

Figure 5. Final grade distributions for 5a) univeristy 1; 5b) university 2; 5c) unviersity 3; 5d) university 4

Summary and Conclusions

This paper described how contextualization of concepts and content of introductory materials courses can positively affect three important factors that affect student learning as described in the book How People Learn. For the first principle, prior knowledge, it has been shown that instruction with contextualized content can activate learners' prior knowledge and promote more effective problem solving. For the second principle, promoting conceptual change, contextualization of content in interactive classroom engagement activities that motivates students with a concept's relevance can improve learning. For the third principle, promoting metacognition, contextualization of content helps students reflect on their learning to bridge ideas from a familiar concrete context of an abstract concept so they can recognize their own personal relationship to these concepts. Examples were given in terms of contextualizing content for prior knowledge with real-world applications through modification of publishers' slide sets and teaching materials. For engagement, contextualized concept maps demonstrated how concepts can be made more relevant with linkage of real-world items to symbols, formulas, and concepts. For formative two-way feedback with Muddy Points an example was given of the context of historic and contemporary aircraft used to illustrate the value of strengthening processes of aluminum alloys. Then faculty responses to students' Muddiest Points showed how the aircraft context could facilitate better motivation in understanding the mechanisms of strengthening.

Student motivation with respect to using the teaching strategy of incorporating real-world applications in contextualizing content was assessed with a new tool, the Student Classroom Survey for Motivation of Contextualization (SCMC). Using Expectancy Value Theory a series of 24 statements were created to assess impact on students' motivational attitude of the use of relevant and contextualized examples in the introductory materials course. The survey consisted of 24 statements based on Expectancy Value Theory on a scale of 1, strongly disagree, to 4, strongly agree. Students agreed or strongly agreed with almost all statements with the following values; 2.58 for expectancy (expectation to succeed); 3.16 for value (of contextualization); and 2.12 for (cost of using contextualization). Thus, expectancy of success of students' believing they would benefit from contextualization was moderately positive. But for the *value component* of motivation students found strong *attainment value* for potential for facilitating learning and strong *utility value* for their future courses and careers. It was found that cost factors were relatively low for implementing contextualization in content and concepts.

It was found that the results from the SCMC supported results questions from another exit survey on Support of Student Learning Strategies from Spring 2014. For the strategy of using contextualized hands-on classroom activities, 91% said it supported or strongly supported their learning. For contextualized mini-lecture, 79% said it supported or strongly supported their learning. Finally, for the statement, "Material I learned in this class will be of value to me after graduation in career or graduate school," 86% agreed or strongly agreed.

When contextualization of content was incorporated with engagement and feedback pedagogy there were very positive outcomes from courses from three institutions in the JTF project. In addition to positive attitude, student persistence achieved a high value of 95% to 97% across four institutions. Additionally, student achievement for four courses at the three institutions over time showed significant improvements in outcomes of final exams. It was found that grade point distributions improved by a half to a full grade while the percent of Ds and Es was reduced by a factor of more than 50%. Overall, the potential for improving engineering undergraduate student outcomes thorough the use of contextualization of content shows excellent potential and should receive greater consideration from engineering instructors.

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