AC 2012-3519: STRATEGIES AND TOOLS FOR ENGAGING AND ASSESSING STUDENTS WITH CYBER LEARNING BY INTERACTIVE FREQUENT FORMATIVE FEEDBACK (CLIFF) IN CORE MATERIALS CLASSES

Prof. Stephen J. Krause, Arizona State University

Stephen J. Krause is professor in the School of Materials in the Fulton School of Engineering at Arizona State University. He teaches in the areas of bridging engineering and education, capstone design, and introductory materials engineering. His research interests include evaluating conceptual knowledge, misconceptions and their repair, and conceptual change. He has co-developed a Materials Concept Inventory for assessing conceptual knowledge of students in introductory materials engineering classes. He is currently conducting research on misconceptions and development of strategies and tools to promote conceptual change in materials courses.

Jacquelyn E. Kelly, Arizona State University

Jacquelyn Kelly is doctoral candidate in science education at Arizona State University. Her master's degree is in materials science and engineering and her undergraduate degree is in physics and chemistry. Her principle research interests are situated in engineering education and include conceptual development, engineering academic language acquisition, and the role of motivation and emotion on these things. She is also invested and passionate about K-12 education as she teaches physics, chemistry, and science foundations at New School for the Arts and Academics, an alternative arts high school.

Dr. Dale R. Baker, Arizona State University

Dale Baker is the former editor of the Journal of Research in Science Teaching and a member of the editorial board of JEE. She is a fellow of the American Association for the Advancement of Science and the American Educational Research Association, as well as an affiliate of the Learning Sciences Institute at Arizona State University. Her research focuses on equity issues in STEM, engineering education, and teacher professional development.

Strategies and Tools for Engaging and Assessing Students with Cyber Learning by Interactive Frequent Formative Feedback (CLIFF) in Core Materials Classes

Abstract

In this paper we are first reporting on the effects on student attitude, learning, and persistence of an active learning project, Just-in-Time-Teaching with Interactive Learning (JiTTIL). We will then discuss how the associated strategies and tools used in the JiTTIL project will be adapted to an interactive cyber-enabled web environment. In the web environment real-time data on student understanding can be collected in the classroom followed by fast formative feedback to students to promote their learning. In the JiTTIL project strategies and tools were developed to promote student engagement in introductory materials classes based on three major principles from the book, How People Learn. The first principle is that instructors should be aware of and utilize students' prior knowledge to inform instruction. Prior knowledge and misconceptions are assessed at semester beginning with a Materials Concept Inventory (MCI) while conceptual change is assessed at semester end by giving the MCI again and calculating conceptual gains. More detail on misconceptions and conceptual gain for five specific topics was determined with pre-post topical concept quizzes. The second principle is for instructors to actively engage students with one another to promote development of their own deep conceptual of content and a framework for understanding, recalling, and using that knowledge. One tool for this is clicker questions, for which 104 multiple-choice questions were created that cover the nine course topics. Another tool to promote conceptual development is a set of Homework Preview Problem Concept Map Quizzes where students must fill in blanks on diagrams of conceptual connections of materials structure and properties. Also, to engage students in content from mini-lectures, engagement activities were created for every class. Finally, the third principle is for instructors to foster student metacognition. This was done with an end-of-class Reflection Points question set that requests students to briefly describe (anonymously) their own class points of: interest; muddiness; and learning about learning. An instructor can use responses to give feedback immediately at the beginning of the next class to address students' muddy points or other issues.

Compared to lecture-based pedagogy, the JiTTIL constructivist pedagogy: increased average conceptual gain (measured by the Materials Concept Inventory) from 18% to 42%; increased class persistence from 85% to 95%; and decreased female withdrawal rate from 40% to 10%. A fall 2011 exit survey found 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 survey results found that: 1) 88% of the students felt the class increased their interest in continuing in their own major; 2) 65% felt instructional strategies 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) 84% would recommend the course to a friend. This paper then describes how strategies and tools of the JiTTIL project will be implemented via the web in a Cyber Learning with Interactive Frequent Formative Feedback (CLIFF*)* project. After implementation, the effectiveness of the cyber-enabled web pedagogy will be studied and compared with the JiTTIL approach to determine the impact on student outcomes and on the ease of implementation and use of the strategies and tools by the instructor.

Introduction

Strategies for Adapting Active Learning tools to a Cyber-enabled Web Environment.

A National Science Foundation (NSF) sponsored project, Just-in-Time Teaching with Inquiry Learning (JiTTIL), significantly increased student conceptual gain in a core materials class compared to earlier classes taught with lecture pedagogy[1]. We are planning to leverage three NSF-supported, cyber-enabled web platforms, designed for easy implementation and broad usage of learning tools, by using the platforms for teaching with the active learning strategies and tools that have been proven to enhance student attitude, learning and retention in core materials classes. The JiTTIL pedagogy, which was designed to engage students and stimulate frequent formative feedback during instruction, will now be cyber-enabled with the potential for easier implementation, usage, and ultimately, broad dissemination. This is now possible due to the recent establishment of three new NSF-supported, web learning and assessment platforms. They are *LectureTools* http://www.lecturetools.com/, *Concept Warehouse* http://cw.edudiv.org, and Concept Inventory Hub (ciHub) (http://dev.cihub.org/). These platforms have been tested and are now being implemented in the classroom. The reactions have been quite positive for the instructor and the students for the introductory materials class with 41 students.

Previously, only limited web usage was possible with activities and assessments with the Blackboard class management system which was augmented with classroom pen and pencil assessments. This approach was cumbersome and implementation of new interactive tools was quite time consuming. As such, the three new web platforms became available for the first time during the Fall 2011 term and appear to have addressed implementation issues. These platforms have excellent functionality, including data analysis and reporting functions, which make them both flexible and powerful. The features and functions of the platforms have potential to: enrich instructional capabilities; reduce time and effort expended teaching; and also provide rich, interactive feedback to both students and instructor for enhanced classroom experiences. This creates opportunities for improved teaching and more effective and efficient learning. As such, we will call this approach Cyber Learning with Interactive Frequent Formative Feedback (CLIFF). The web platforms also allow frequent opportunities for bilateral feedback between students and instructor with follow on by instructor and students. Such frequent formative feedback has been shown to promote more effective learning compared to summative only feedback, which is usually given to students only after quizzes, tests and homework[2, 3].

Implementing Classroom LEARN Tools on *LectureTools* and *Concept Warehouse* Web Sites

The teaching and learning supplements or tools used in the materials classes were created in JiTTIL are referred to here as Learning by Engagement, Assessment, and ReflectioN (LEARN) tools for use by students in-class and out-of-class. Since reliable cyber-learning hinges on effective and efficient implementation of course materials and the LEARN tools on three cyber-enabled web platforms, they will be described in moderate detail here to illustrate their simplicity, functionality, and ease of use.

In-class LEARN tools will be implemented on student lap tops or tablets or lab table-top computers with a real-time, interactive web platform in *LectureTools*, which was developed by Prof. Perry Samson at the University of Michigan. This site will be sustainable into the future since it is now a company that grew out of a 2005 NSF CCLI grant. *LectureTools* converts PDF or PPT files to JPG files, which are stored in the "cloud" (a high capacity server). The instructor can use a mouse pointer or tablet writer to write or do calculations directly on his/her JPG slides with the script appearing immediately on the screens of all students, each of who has their own account (cost is $15/semester). This account also gives them access to their own slide file set for each class with immediate access to both the instructor slide set and their own slide set anytime and anywhere. They can also take notes in a box on their own slide file and interact with the instructor by sending him/her comments and questions as well as participating in activities directly from their own screen. They can also send in from their cell phone comments, questions, and activity responses. Thus, the *LectureTools* platform is much simpler and more efficient than the Blackboard class management system. It also replaces the need for clicker hardware in personal response systems, which sometimes has hardware compatibility issues with certain computer operating systems. Thus, *LectureTools* is efficient and simple and easy to use, making it a time saver for both instructor and students. The learning curve for *LectureTools* is quite shallow also, since it takes about a one-hour webinar for an instructor to learn the system. There is also added functionality for the instructor slide set since he/she can augment the JPG slide file in "Prepare" mode with individual slides for multiple choice clicker questions (which give bar graph results of student response), free response text input slides, sort-and-order slides, and point-and-click to mark a spot on image slides. The Concept Inventory Hub (ciHub) (http://dev.cihub.org/) is interactive, cyber-enabled web site being developed at Purdue by Terri Reed Rhoades and P. K. Imbrie. It is for development, testing, and use of Concept Inventories for engineering education. At present there are eight engineering science concept inventories on the beta site. Instructors can use the site for no charge by applying for access, after which students can be tested by entering their email addresses into the system to become valid users. There concept inventories have sets of multiple choice questions for which students make a single choice. There is also an option for student responses on each question to give "reasoning for the answer they chose", as well as the degree of confidence in their answer. The platform has the capability to process, analyze, and report the results from either pre-semester, post-semester, or post-pre semester sets of results. These results would give conceptual knowledge for baseline entry, exiting conceptual knowledge, and conceptual gain over the course of the semester.

For out-of-class LEARN tools, mainly assessments, they will be implemented on the interactive, cyber-enabled web site of *Concept Warehouse* developed by Prof. Milo Koretsky at Oregon State University. The *Concept Warehouse* was designed to promote and facilitate conceptual learning in Chemical Engineering by having large sets of concept-based clicker questions (or ConcepTests) for core chemical engineering classes. An instructor could choose selected sets of slides on a given topic within any of five areas of core classes and administer them to students via the web in-class or out-of-class as activities, quizzes, tests, self-study guides, etc. Each multiple-choice question slide also requests of students their reason for selecting an answer (with a free response box) and the degree of confidence in their answer with a 1-5 Likert scale. The instructor has immediate access to the results inside or outside of the classroom and so can address student-learning issues by adjusting teaching strategy and instruction. The responses for the answer, student reasoning, and confidence level can also be downloaded directly and converted into an excel file. In summary, the functionality and accessibility of the three web platforms give them the capability to take responses generated by students, while using interactive tools, and then score, analyze, and report results directly on the sites (or with downloads) instead of having to carry out these processes manually as was done previously in

JiTTIL. Standardized input and output for each platform also allows for easier comparison between data sets collected at different institutions using the same tool formats. This facilitates direct comparison of results that can reflect differences in cultures, settings, and populations at the institutions. There is excellent potential in using these cyber-enabled platforms for enhancing teaching and learning and student achievement, as well as each day's classroom experience.

It is hoped that the will be ease of implementation with the use of the interactive cyber-enable platforms because, in the past, new technologies have sometimes been a barrier to scaling innovative learning strategies and materials. In the JiTTIL project the Just-in-Time-Teaching pedagogy used pre-class, web-question student responses as feedback to the instructor so he/she could adjust daily class design. Today, the cyber-enabled web platforms used in CLIFF expand and extend technology functionality beyond JiTTIL so results at different time intervals of student-based assessments can provide the *fast* frequent formative feedback needed to adjust instruction to address serious learning issues such as robust misconceptions and difficult concepts[5]. For example, in *LectureTools* students can send anonymous questions and comments to the instructor who can assess the severity of an issue (by number and intensity of responses) and can answer in real time if so desired. Thus, student-learning issues in class can be addressed immediately.

Background

Tools Used in JiTTIL Project for Measuring Student Attitude, Learning, and Persistence.

The JiTTIL constructivist pedagogy has been used for the last six semesters and tools used to measure change include the following. The Materials Concept Inventory (MCI) is a 30-item, multiple-choice, pre-post course instrument[4]. This summative instrument reveals misconceptions and measures baseline conceptual knowledge of a subject at the semester beginning and at semester end measures conceptual gain the extent to which misconceptions were repaired. Five Pre-Post Topical Concept Quizzes (PPTCQ) also measure baseline conceptual knowledge of a given topic before teaching it and conceptual gain on the topic after it has been taught. It assesses finer granularity of a student's conceptual understanding of a given topic, as well as revealing students' misconceptions and knowledge gaps on a given topic. The shortest time scale is in class with activities and by using "Clicker Questions" which are multiple-choice questions that embed misconceptions in the answer choices, known as distractors. This formative assessment gives immediate formative feedback that can inform the instructor (as well as the student) of student understanding (or lack thereof) of the current content being taught. Formative feedback at this stage of instruction has been shown to be very effective and can be carried out in real time. An advantage of using Lecture Tools (or *Concept Warehouse*) is that no clickers are necessary since responses by students can be sent via wifi with a laptop, iPad, or cell phone without a "clicker" tool. Finally, there is a semester-end student self-perception survey called the Student Evaluation of Instructional Strategies & Personal Impact (SEISPI) which evaluates the teaching strategies and classroom experiences with respect to support of student learning and also with respect to personal impact on attitude about the course and students' futures. The platforms can capture students' reactions and commentary on the classroom activities and experience in real time. The nature of each of each of the tools described here, along with recent results from the JiTTIL project will now be presented.

Materials Concept Inventory (MCI) for Measuring Student Achievement.

Two decades ago the Force Concept Inventory (FCI) was created by Hestenes et al. to measure conceptual understanding of physics students in Newtonian mechanics[6]. It was found by Hake that lecturing was far less effective for learning than "interactive engagement"[7]. For materials classes a similar instrument called the Materials Concept Inventory (MCI) was created by Krause, et al[4]. It is a 30-item, multiple-choice instrument to measure conceptual understanding and conceptual change across a semester of a core materials class. It is a valid and reliable instrument that has been able to differentiate gains in conceptual understanding due to differences in pedagogy. This is shown here in Figure 1, which shows that gains for the JiTTIL engagement pedagogy taught Fall 2011 have a much higher average gain of 42% vs. 18%, than 2002 lecture pedagogy. It shows that gains are higher in all five topical areas of bonding, crystal structures, mechanical properties, polymers, and electrical properties. The reasons for higher gains are using engagement pedagogy and addressing misconceptions with effective strategies and tools for repairing them. Administration of the MCI will be shifted to the new NSF-supported web site, the Concept Inventory Hub (ciHub) (http://dev.cihub.org/) which is an interactive, cyber-enabled web site for development, testing, and use of Concept Inventories for engineering education.

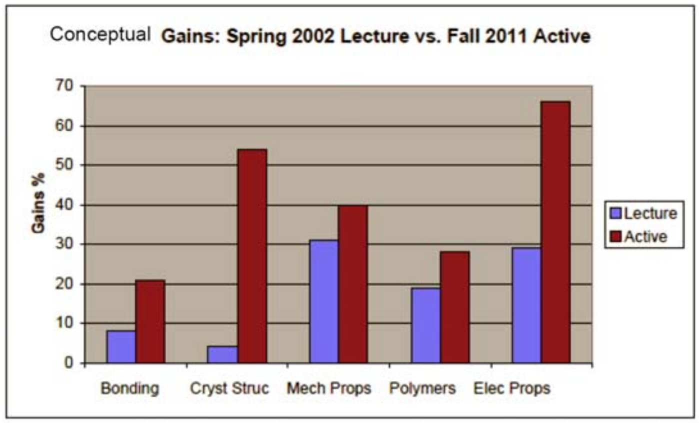

Fig. 1. MCI Conceptual Gains in 5 Topics for Sp 02 Lecture vs. F11 Active Classes

Web Based Pre-Post Topical Concept Quizzes (PPTCQ) to Measure Conceptual Change

In the book, *How People Learn*[8], one important principle for more effective teaching and learning is that instructors need to be aware of students' prior knowledge so instruction can be appropriately adjusted. To uncover this prior knowledge formative assessment tools were created in the JiTTIL. One was a set of Pre-Post Topical Concept Quizzes, given before and after each of five topics in the materials class. In addition to the MCI to uncover this prior knowledge, formative assessment tools were created in JiTTIL. One was a set of Pre-Post Topical Concept Quizzes, given before and after each of five topics in the materials class. Each Pre-Topic Concept Quiz, revealed a baseline of knowledge as well as misconceptions and knowledge gaps on a topic[9]. The same tool, given Post-Topic, gave conceptual gain (and therefore effectiveness of instruction) as well as revealing robust

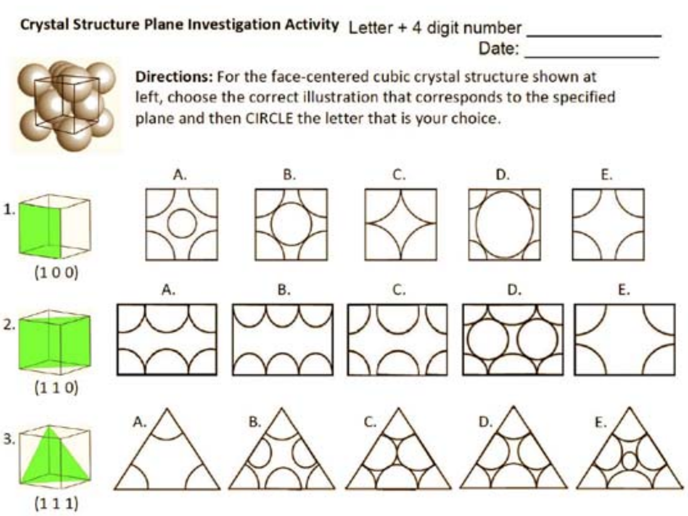

Figure 2. Crystal Structure Concept Pretest from earlier pencil - paper test

misconceptions, which still remain after instruction. For JiTTIL these tools were given as pencil and paper instruments and evaluated by hand with appropriate rubrics. While this type of tool is valuable for revealing misconceptions, it is also time consuming to score and evaluate the results by hand. These five instruments are now being reworked into five multiple choice question sets, like the example shown in Figure 2 for Crystal Structures. These will be administered interactively outside of class on the *Concept Warehouse* web platform. Using the web outside of the classroom for the five Pre-Post Concept Quizzes and the pre-post course MCI will save more than three hours of instructional time as well as tens of hours of time in hand scoring the results.

The Pre-Post Topic Concept Quizzes revealed many misconceptions, a few of which are here described. *Bonding misconceptions* included: "Covalent bonding is a “bond between a nonmetal and a metal”; a van der Waals bond is “a weak bond where atoms are magnetized.”; *Crystal structure misconceptions included*: a (111) plane in a BCC structure is usually drawn going through the body-center atom when it does not. *For metal paper clip deformation misconceptions include*: “Atoms rub together creating heat and breaking the particles up, melt the clip”; grain boundaries “move,” “stretch,” or “bend.” *Polymers deformation misconceptions* include: in rubber band stretching “atoms are becoming softer; in p*lastic fork breaking* “Atoms snap at the atomic level”; and for s*tretching of a PE bag* “Atoms become softer as they are stretched and begin to break”. Electrical Properties misconceptions include: *Adding a small amount of copper to zinc "*will increase conductivity because the copper is very conductive"; *Add a small amount of As to Si causes conductivity to* decrease because of the impurity with less conductivity”; or causes conductivity to “go down; an impurity is in the way.”

Class-End Reflection Points & Subsequent Discussion

Another formative assessment is a class-end Points of Reflection assessment[10]. To date these reflections have been pencil and paper class end single sheets that had to be transcribed into an Excel matrix and then summarized by the involved student and the instructor. The use of the *LectureTools* web platform, which has a student written response function, will greatly facilitate data collection and analysis. At the end of class students were requested to describe their own: "Most Interesting Point" (1-5 Likert scale) "Muddiest Point" (1-5 Likert scale) "What Did You Learn About Your Learning? Point". The Muddiest Point can reveal what students consider to be a difficult or confusing concept, especially so when a large fraction of the class rates a given concept at a 4-5 average on the 1-5 Likert scale. High rating averages of the "Most Interesting Point" can reveal

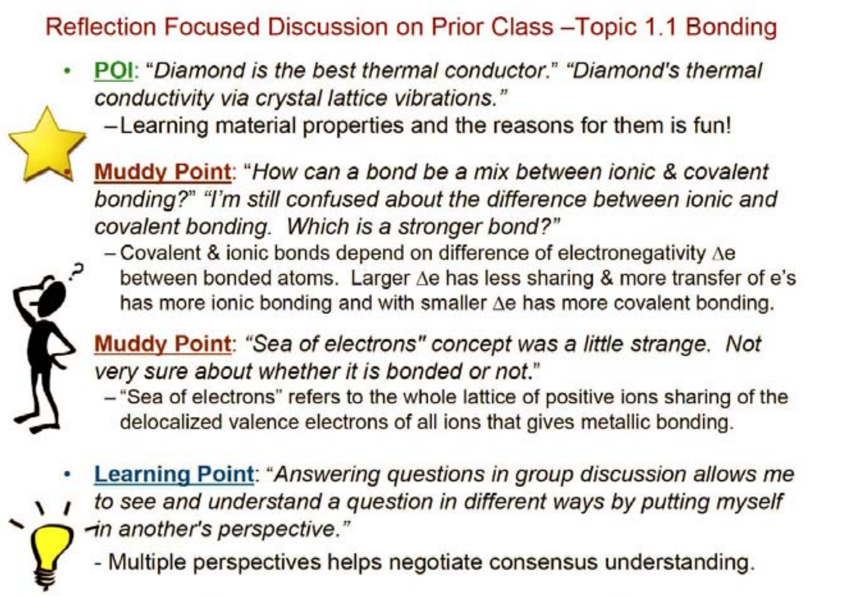

Figure 3. Class-Start Reflection Discussion from Prior Class Reflection Points.

positive student attitude on a given topic, and can help motivate students in their classroom performance. The "What Did You Learn About Your Learning" point is intended to promote metacognition. In effect, students are empowered when involved in designing their own instruction, Research has shown that attending learning issues as quickly as possible with immediate feedback is most effective for motivation and learning[3]. This assertion is supported by responses from Daily Reflections and the final day, semester wrap-up Meta Reflection on Reflections. Some quotes on the personal impact of filling in Meta Reflection on Reflections are shown below. Some quotes include:

Wrap-up on Points of Interest:

Across a semester what was the impact of Interest Points on your attitude & interest?
"Relating things to my daily life helps me to retain info better"

Wrap-up on Muddiest Points:

Did your responses to Muddiest Points 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 the start of next class help your understanding (or not)?
"Questions other people asked helped because, many times they were questions I didn't think to ask"

Wrap-up on Learning Points:

Did your responses on Learning Points help you think about and monitor your learning?
"It allowed me to see the value in working in groups"

Role of In-class Activities and Frequent Formative Feedback on Student Learning

Figure 4. Sort & Select Activity Connecting Properties, Material, Bonding & Processing

Immediate and frequent feedback plays an important role in the progression of a learner from the level of "novice" toward "expert" understanding & performance in a given domain. In a review on the acquisition of expert skills, Ericsson cites as one important condition for optimal learning and improving performance is that learners should *receive immediate and informative feedback and knowledge of results of their performance* on a given task[11]. In the JiTTIL project there were regular and frequent types of feedback including: daily Preview Problem Concept Map Quiz discussions, daily Prior Class Muddiest Point Discussions, multiple-choice Clicker Question discussions, and discussions during Concept in Context classroom activities like the sort and match motorcycle parts in Figure 4. This was critical to the students understanding of content and their positive attitude as shown by the Fall 2011 exit survey results on Student Evaluation of Instructional Strategies & Personal Impact survey that gave the following results of student perceptions of teaching strategies used in the class. For Team Engagement Strategy questions on strategies that supported student learning: 1) 85% of the students felt team-based problem solving and discussions did; 2) 77% felt reporting out to class did; and 3) 93% felt hands-on team engagement activities did. The *Lecture Tools* in-class interactive web platform will be able to now provide feedback on each team engagement activity through the instructor feedback comments function. Acquiring such data previously was difficult, but now, such feedback should give the instructor insights on student thinking so he/she can adjust learning strategies when necessary. Additionally, students will be able to send questions to the instructor in real time. This student feedback capability of *LectureTools* should facilitate the desired principle of immediate feedback followed by fast feedback to the students.

The positive impact of classroom feedback on student learning has been demonstrated by Crouch and Mazur[12] who reported significant FCI gains in using "Peer Instruction" which uses student pair discussion of class-based clicker questions. It was also reported that, in SCALE-UP[13] studio physics courses with pre-class questions and inquiry activities with the two-way feedback in Socratic dialogue, students: have enhanced conceptual understanding, problem-solving ability, and motivation; fail less frequently than in conventional courses; and perform better in subsequent courses in physics and engineering. There were decreases in failure rate, highest among female and minority students, which they attribute to supportive social interactions.

Pre-class Preview Problem: Concept & Vocabulary Building Concept Map Quizzes

An innovative learning aid, or tool, are pre-class Concept Context Map (CCmap) Preview Problems, with an example shown in Figure 5 for Atomic Bonding, to be used in CLIFF instruction . This tool scaffolds a conceptual framework for a given topical area, as well as building vocabulary- since there are more than 400 terms and concepts to learn. This is done by students filling in blanks with terms from the selection bank in the upper left hand corner.

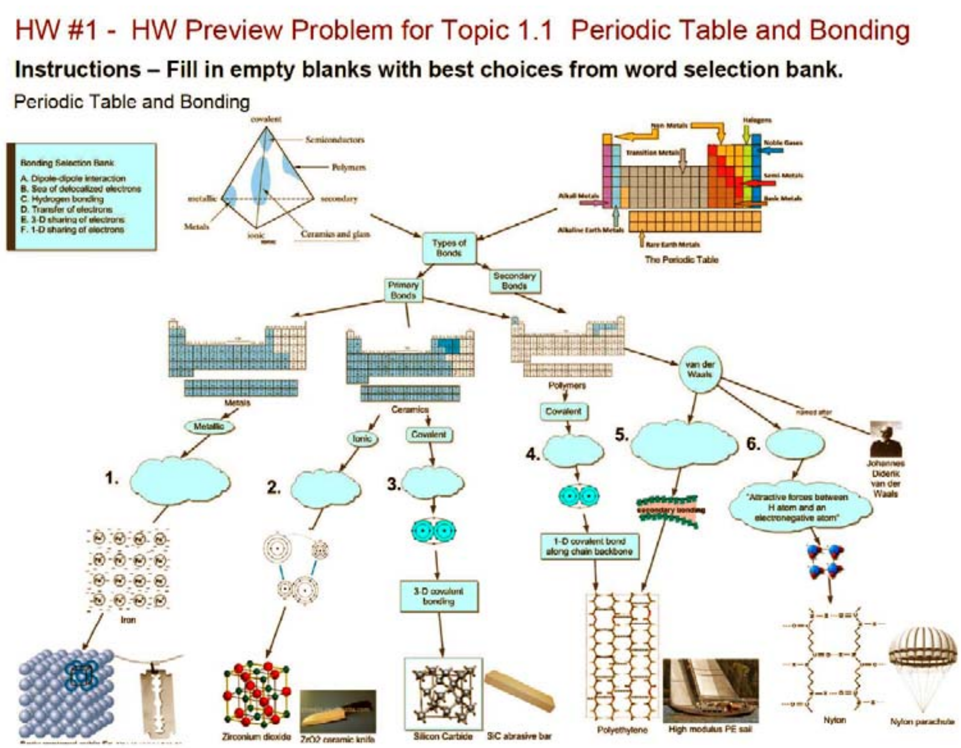

Figure 5. Atomic Bonding Concept-Context Preview Problem

Additionally, the multiple representations of concepts in CCMaps reveal the ways in which various aspects of a concept can be related and connected. For example, the CCMap Preview

Problem in Figure 5.links abstract concepts of the Periodic Table to different types of atomic bonding and the crystal structures for the concrete real-world items. For example the figure above shows a steel razor blade with metallic bonding and a nylon parachute with 1-D polymer chain backbone with covalent bonding surrounded by the 2-D hydrogen bonding between the chains. Thus, we see that CCMaps can show the framework of related concepts in a subject area and use "expert-like" multiple expressions to represent them in ways that experts might use in their own visual and verbal communication about the subject. In the exiting survey of a Spring 2011 core materials class 100% of the 31 students said that CCMaps supported or strongly supported their learning.

Effect of Engagement and Content Contextualization on Student Motivation & Persistence.

In the six semesters for which materials courses were taught by JiTTIL with student engagement methods, persistence increased to 95% compared to persistence of 85% with the six earlier lecture-based classes. This is shown in the adjacent graph. Also, in comparing lecture to constructivist instruction, it was found that female withdrawal rate decreased from about 40% to about 10% for the same classes. These improvements agree with the results of Marrs, Blake, and Gavrin who found that, compared to lecture-based introductory biology courses, courses taught with JiTT and inquiry activities, students withdrawing or receiving a D or F dropped from 33% to 18%[14]. 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[15]. Two aspects of motivation have been shown to impact learning the most. These are the degree to which students think that they are capable of completing a learning task (*self-efficacy*)[16] and the degree to which they think that the activity is valuable to their long term future[17, 18]. 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.

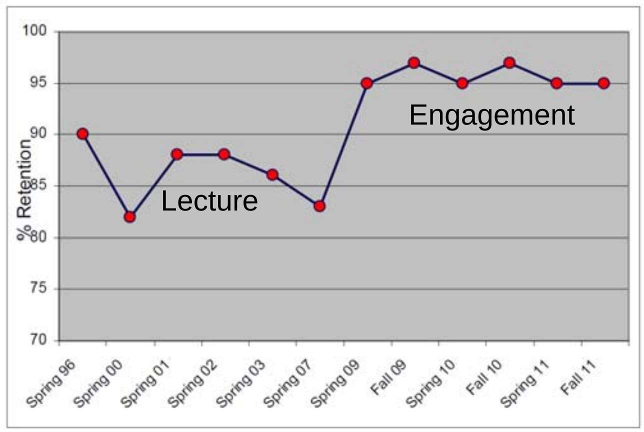

Figure 6. % Retention in Core Material Classes Taught by the PI over time

It has also been shown that motivation can be increased when students recognize and identify with a concept's relevance, significance, and possible value to their own future. As discussed earlier, when students are learning to bridge ideas from concrete contexts of a material with the familiar, such as a razor blade or a parachute, to abstract concepts, such as atomic bonding, they also recognize their own relationship to these concrete contexts. When presented with situations related to these contexts, students can be better motivated to learn and continue on in engineering. This directly reflected in the affective portion of the previously cited exit SEISPI survey for the Fall 2011 core materials class. In particular, for affective factor questions, the results found that the percentage of students who agreed or strongly agreed was: 1) 65% who felt that instructional strategies in the course were more motivating than those in other classes; 2) 77% felt that material learned would be of value to them after graduation in career or grad school; 3) 92% felt that the course helped them to see the relevance of engineering to real-world needs; and 4) 84% would recommend the course to a friend. These types of positive outcomes may have also positively affected student persistence over time.

Using Engagement and Feedback Pedagogy for Diversity in Engineering Education.

Teaching diverse populations may require awareness of cultural or ethnic incongruencies that can impede learning. Interactions of members from different cultural groups may create barriers to learning due to factors such as differences in ways of thinking, verbal communication, and use of processes of evidentiary-based science[19], which can impact retention. Busch-Vishniac and Jarosz recommended that, retention of women and minorities can be improved with, more teamwork early in a curriculum, use of real world contexts, socially relevant design projects like the recycling activity in Figure 7, and a curriculum tied to values of women and the cultures of minorities[20]. Tannen documents that men and women use language differently in conversation and have different goals and values when engaging in conversations and debate[21]. Furthermore, our own research indicates that women are marginalized in engineering group work[22]. Since minorities that engage by working in groups share many of the status issues with women[23, 24], we believe that similar patterns will emerge for both of these under-represented groups in engineering which could affect retention and GPA as well as problem solving ability[25, 26]. In fact, JiTTIL pre-class question sets were designed so they would be gender and diversity friendly, and contextualized for societal relevance [27, 28]. As such, the JiTTIL tools have potential to reduce disparities in achievement that results in lower grades, loss of self-confidence, and degraded retention. This is supported by the fact that they improved class persistence as was shown in Figure 6. Thus, part of the future study on CLIFF will be to determine effectiveness of JiTTIL instructional tools in the web environment.

Figure 7. Socially Relevant Activity Recycling Plastic Waste to Proper Bin

Summary and Conclusions

Information will be acquired and knowledge gained to compare the effect on student attitude, learning, and retention for using CLIFF delivery versus JiTTIL delivery of the strategies and tools developed in the JiTTIL project. Another factor to be studied is on ease of implementation of CLIFF on cyber-enabled interactive web learning platforms and how instructors use assessment results as feedback for adjusting instruction. Another potential outcome is the determination of the effect of CLIFF on engagement activities and assessments on student learning and attitude if the approach is adapted by other institutions. This will help inform the potential for scaling the approach more broadly if it is successful. This information can inform the design and development of teaching and learning strategies and associated instructional tools and practices for more effective teaching and learning which may also have an effect on diverse populations. The broad availability of the web-based CLIFF Tool Kit with innovative components can also allow selective use of desired components by individual instructors. This would have the potential to facilitate adaptation of as least some of the CLIFF approach and promote diffusion of its innovations.

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