120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013
ATLANTA
Paper ID #7863

# Just-in-Time-Teaching with Interactive Frequent Formative Feedback (JiT-TIFFF or JTF) for Cyber Learning in Core Materials Courses

**Prof. Stephen J Krause, Arizona State University**

Stephen J. Krause is professor in the Materials Science Program in the Fulton School of Engineering at Arizona State University. He teaches in the areas of engineering education design, 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 with cyber enabled tools for teaching and learning and assessment of student attitude, achievement, and persistence.

**Dr. Dale R Baker, Arizona State University**

Dr. Dale Baker is a fellow of the American Association for the Advancement of Science and the American Educational Research Association. Her research has focused on equity issues in science and engineering, teaching and learning in science and engineering and teacher professional development in science and engineering. A new area of research she is exploring is the issues surrounding increasing the number of individuals with disabilities in science and engineering and the role of adaptive technologies in increasing participation in science and engineering.

**Dr. Adam R Carberry, Arizona State University**

Dr. Adam R. Carberry is an assistant professor at Arizona State University in the College of Technology and Innovation's Department of Engineering. He earned a B.S. in Materials Science Engineering from Alfred University, and received his M.S. and Ph.D., both from Tufts University, in Chemistry and Engineering Education respectively. Dr. Carberry was previously an employee of the Tufts' Center for Engineering Education and Outreach and manager of the Student Teacher Outreach Mentorship Program (STOMP).

**Dr. Milo Koretsky, Oregon State University**

Dr. Milo Koretsky is a professor of Chemical Engineering at Oregon State University. He currently has research activity in areas related to thin film materials processing and engineering education. He is interested in integrating technology into effective educational practices and in promoting the use of higher level cognitive skills in engineering problem solving. Dr. Koretsky is a six-time Intel Faculty fellow and has won awards for his work in engineering education at the university and national levels.

**Mr. Bill Jay Brooks, Oregon State University**

Bill Brooks is a Ph.D candidate in the School of Chemical, Biological, and Environmental Engineering at Oregon State University. As an undergraduate he studied hardware engineering, software engineering, and chemical engineering. Bill has been involved in the development of several educational software tools including the Virtual BioReactor, the Web-based Interactive Science and Engineering (WISE) Learning Tool, and the AIChE Concept Warehouse. His dissertation is focused on technology-mediated, active learning techniques and the mechanisms through which they impact student performance.

**Ms. Debra Gilbuena, Oregon State University**

Debra Gilbuena is a Ph.D. candidate in the School of Chemical, Biological, and Environmental Engineering at Oregon State University. She currently has research focused on student learning in virtual laboratories. Debra has an M.BA, an M.S., and four years of industrial experience including a position in sensor development, an area in which she holds a patent. Her dissertation is focused on the characterization and analysis of feedback in engineering education. She also has interests in the diffusion of effective educational interventions and practices.

**Dr. Cindy Waters, North Carolina A&T State University**
**Casey Jane Ankeny, Arizona State University**

Dr. Casey J. Ankeny is a post-doctoral fellow in engineering education at Arizona State University and an adjunct professor at Scottsdale Community College. Currently, she is working under Dr. Steven Krause to investigate cyber-based student engagement strategies with frequent, formative feedback in introductory courses. Dr. Ankeny 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. Here she studied shear and side-dependent microRNAs in human aortic valvular endothelial cells and taught six different biology and engineering courses. Dr. Ankeny aspires to employ student engagement strategies in the context of biomedical engineering education in the future.

# Just-in-Time-Teaching with Interactive Frequent Formative Feedback (JiTTIFFF or JTF) for Cyber Learning in Core Materials Courses


## Abstract

In this new NSF-sponsored Type 2 TUES (Transformation of Undergraduate Engineering in STEM) project, we are using engagement, assessment, and reflection tools developed in a successful CCLI Phase 1 project and are adapting them to the internet as tools for an interactive cyber-enabled web learning environment. They include: 1) *Blackboard*, 2) *Concept Warehouse* (cw.edudiv.org), 3) *Concept Inventory Hub* (ciHub) (dev.cihub.org/), 4) *YouTube Video Tutorial Screencasts for Materials Concepts* (www.youtube.com/user/MaterialsConcepts), *Google.docs Survey* (docs.google.com), and a vocabulary building site, Quizlet (http://quizlet.com/matsciasu). *Blackboard* is a web-based, class management system for education organizations that has a wide variety of tools available including: class note distribution; quiz and survey administration; communication; and grade recording, tracking and analysis. The *Concept Warehouse* is a cyber-enabled site for facilitating conceptual learning in Chemical Engineering with large sets of concept-based clicker questions (or ConcepTests) for core chemical engineering classes. An instructor can immediately access results to from *Concept Warehouse* to address student-learning issues by adjusting teaching strategy and instruction. The *ciHub* is a cyber-enabled site for the administration and analysis of *Concept Inventories* for engineering education. The *Materials Concepts* YouTube site is the location of a series of Muddiest Point YouTube Tutorials as well as an Interactive Quick Quiz on Eutectic Phase Diagram Calculations and Microstructures. It uses short screencast tutorials to address students' Muddiest Points, i.e. content that is still unclear from class. Using these cyber-enabled tools in and out of class has potential to increase effectiveness and efficiency of learning using frequent formative feedback to students. Innovations from CCLI 1 are reflected in a new project title, Just-in-Time-Teaching (JiTT) with Interactive Frequent Formative Feedback (*JiTTIFFF* or *JTF*). The approach is being implemented in four settings that have diverse populations: Arizona State University, North Carolina A&T State University, Oregon Institute of Technology, and Oregon State University. The CCLI 1 showed strongly positive student outcomes when new strategies and tools were used for instruction informed by a multi-level, assessment-driven frequent formative feedback loops and contextualization of activities and assessments with real-world applications. Compared to lecture-based pedagogy, constructivist pedagogy showed greater conceptual learning gains, improved student attitude, and increased class persistence. In this paper we are reporting on the benefits and issues of implementing classroom change using the JTF strategies with a particular emphasis on the different methods of using cyber-enabled web tools to provide frequent formative feedback to students. The methodology and impact of implementing frequent formative feedback in the JTF project is discussed along with the impact on student's attitude, achievement and persistence. Overall, innovative new approaches to providing feedback to students are being employed including: Clicker Questions (ConcepTests and Socrative.com); Muddiest Point YouTube Video Tutorial Screencasts; Muddiest Point restructured slide sets and consolidated lecture-by-lecture course materials on Blackboard; and Homework Preview Problems. Results have shown very positive reactions by students to such strategies, as well as improved learning and retention.

## Introduction

In this TUES Type 2 project we are using engagement, assessment, and reflection tools developed in a successful CCLI Phase 1 project and adapting them to an interactive cyber-enabled web environment. Using the tools in and out of class has potential to increase effectiveness and efficiency of learning using frequent formative feedback to students. Innovations from CCLI 1 are reflected in a new project title, Just-in-Time-Teaching with Interactive Frequent Formative Feedback (*JiTTIFFF* or *JTF*). The tools for the interactive cyber-enabled web environment include: 1) *Blackboard*, 2) *Concept Warehouse* (http://cw.edudiv.org), 3) *Concept Inventory Hub* (ciHub) (http://dev.cihub.org/), 4) *YouTube Video Tutorials for Materials Concepts* (www.youtube.com/user/MaterialsConcepts), a *Google.docs Survey Tool* (http://docs.google.com), and a vocabulary building site, Quizlet (http://quizlet.com/matsciasu ). *Blackboard* is a web-based, class management system for education organizations that has a wide variety of tools available including: class note distribution; quiz and survey administration; communication; and grade recording, tracking and analysis. The *Concept Warehouse* is a cyber-enabled site for facilitating conceptual learning in Chemical Engineering with large sets of concept-based clicker questions (or ConcepTests) for core chemical engineering classes. An instructor can immediately access results to address student-learning issues by adjusting teaching strategy and instruction. An alternative clicker site called socrative.com, allows students to participate in exercises and games using smartphones, laptops, and tablets. The *ciHub* is a cyber-enabled site for the administration and analysis of *Concept Inventories* for engineering education. The *Materials Concepts* YouTube site is the location of a series of Muddiest Point YouTube Tutorials as well as an interactive quick quiz which uses short screencast tutorials to address students' Muddiest Points, i.e. content that is still unclear from class. Using cyber-enabled tools in and out of class has potential to increase effectiveness and efficiency of learning using frequent formative feedback to students, as emphasized in this paper. The tools allow frequent opportunities for bilateral feedback between 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 after quizzes, tests and homework [1, 2].

## Background

In the JTF project there are collaborations between Arizona State University, a large public University, North Carolina A&T, a medium-size, historic African American university; Oregon Institute of Technology, a medium-size technology institute, and Oregon State University, a medium-size, west coast university. Project participants, organizations, and roles are shown in Figure 1. Interactions between these institutions offer not a only a chance to test the effectiveness of the *JTF* approach in new settings with diverse populations, but to also test the ease of implementation of the interactive cyber-enabled platforms. In the past, new technologies sometimes have barriers to scaling innovative learning strategies and materials. In the earlier CCLI 1 project the Just-in-Time-Teaching pedagogy used

| |
|---|
| PI Steve Krause – ASU |
| co-PI Terry Alford, Candace Chan, Adam Carberry - ASU |
| co-PI Cindy Waters - North Carolina A&T |
| co-PI Joe Stuart – Oregon Institute of Technology |
| co-PI Brady Gibbons – Oregon State University |
| co-PI *Web* Milo Koretsky– Oregon State University |
| Advisory Board - Karl Smith, John Baglin, Kevin Trimble |
| External Evaluator – Peggie Weeks; Internal – Dale Baker |

Figure 1. JTF Project participants roles and organizations.

pre-class, web-question student responses as feedback to the instructor so he/she could adjust daily class design. Today, the cyber-enabled web tools used in *JTF* expand and extend technology functionality beyond JiTT 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[3]. For example, in using the clicker questions sets on the Concept Warehouse or Socrative platforms, the instructor can immediately access the results of the students and adjust instruction to address misconceptions or other issues. Thus, student-learning issues in class can be addressed immediately. A blog as well as monthly meetings are implemented to provide opportunities for discussions of common student learning issues and barriers and approaches to address them and the successes of such interventions. This helps determine what opportunities, benefits, and barriers exist for implementation of JTF by different instructors at different institutions.

The pedagogical approach used in the JTF project is constructivism, which espouses the belief that students learn most effectively by constructing their own knowledge and refers to learning as conceptual change[4]. *How People Learn* discusses how cognitive processes act to achieve conceptual change, which occurs through modification of a student's conceptual framework[5]. The framework is comprised of *mental models*, which are transformed representations of real-world systems or phenomena called *modeled target systems or phenomena*[6]. As such, *mental models* are defined as simplified, conceptual representations that are personalized interpretations of *modeled target systems or phenomena* in the world around us. Thus, the transformed *modeled target systems or phenomena* turn into the *mental models*, which become more visible or comprehensible to the individual[7]. Useful *mental models* allow us to understand, explain, and predict behavior of systems and phenomena, whereas faulty *mental models*, which lead to misconceptions, cannot. Frequent formative feedback is very effective at repairing misconceptions because students are allowed to immediately reflect on and rethink their faulty mental models and replace them with correct scientific consensus models.

**Frequent Formative Feedback with Concept Quizzes**

| | | Pre | Post | T#1 |
|---|---|---|---|---|
| Increased temperature causes the length of a engineering part to increase because the: | 1) Atoms are getting larger | 4% | 6% | 0% |
| | 2) Bonds get weaker so atom vibration amplitude increases | 54% | 67% | 41% |
| | 3) Atom vibration amplitude increases asymmetrically | 22% | 18% | 59% |
| | 4) Bond strength of valence electrons decreases | 20% | 6% | 0% |
| | 5) Atom's electron clouds become fuzzier | 0% | 3% | 0% |

Figure 2. Pre-Post Results of Concept Quiz on Atomic Bonding.

One popular, widely used approach for rapid in-class feedback to students is the use of Concept Quizzes, which are really formative assessments because they assess a small segment of content within the course. An important interactive web tool is the Concept Warehouse, developed by Prof. Milo Koretsky at Oregon State University. It is 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 can choose a selected set of questions and administer them via the web in-class or out-of-class. Each multiple-choice question slide also requests of student their reason for an answer (with a free response box) and degree of confidence in their answer with a 1-5 Likert scale. These are formative assessments used as immediate feedback tools to inform the instructor 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. In the JTF project, the results of the Fall 2012 semester are found later in the Survey of Student Evaluation of Instructional Strategies & Personal Impact. This survey evaluates the impact of teaching strategies and classroom experiences on support of student learning and personal impact on attitude of the course on students' future goals.

**Frequent Formative Feedback with Class-End Reflection Points & Subsequent Discussion**

A critical tool for frequent formative feedback assessment is the next-class response to a previous set of student responses to class-end Points of Reflection[8] as shown in Figure 3. Such reflections are able to promote metacognition in students thinking and also promote instructor reflection on his/her classroom practice. 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 *Concept Warehouse* web tool, which has a student written response function, will greatly facilitate data collection and analysis.

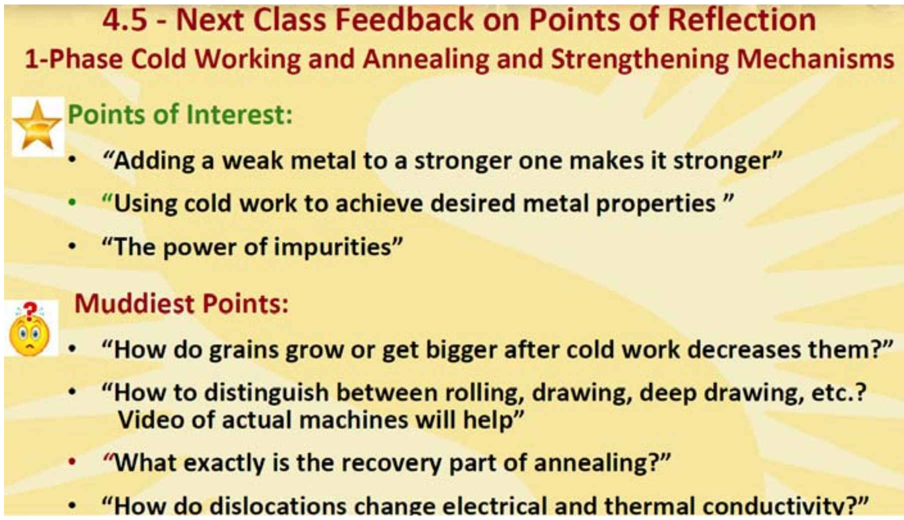

Figure 3. Class-Start Feedback from Previous-Class Reflections

At the end of class students are asked to describe their own: "Most Interesting Point" (1-5 Likert scale) and "Muddiest Point" (1-5 Likert scale). 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 the concept at a 4-5 average on a 1-5 Likert scale. High rating averages of the "Most Interesting Point" can reveal positive attitude toward a specific technical phenomenon or real world example on a given topic, and foster students' motivation in their classroom performance. In effect, students are empowered in their learning when they provide input to their instruction. Research shows that addressing learning issues quickly with immediate feedback is very effective for improving motivation and learning[2]. This assertion is supported by responses from Daily Reflections and a final day, semester wrap-up, Meta Reflection on Reflections, as shown in Figure 3b.

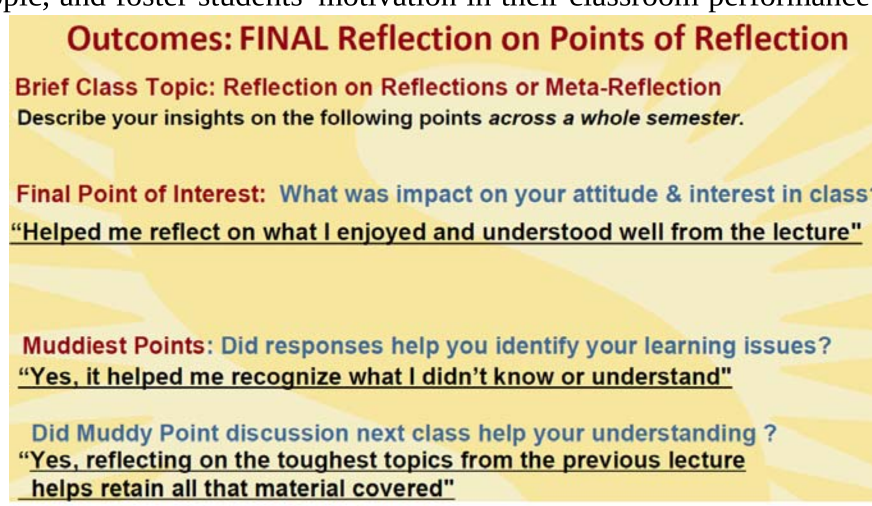

Figure 3b. Meta-Reflection on Entire Semester of Reflections.

## Frequent Formative Feedback with In-class Engagement Activities

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, et al.[10] cites that 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. In CCLI 1, and now the JTF project, there are frequent types of feedback including: daily Preview Problem Concept Map discussions; daily Prior Class Muddiest Point Discussions; multiple-choice Clicker Question discussions; and discussion during Concept in Context classroom activities like the sort and match motorcycle parts in Figure 4.

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

## Just-in-Time-Teaching and Formative Feedback with Pre-class Preview Problems

Another type of innovative learning tool is the pre-class Concept Context Map (CCmap) Homework Preview Problem. An example of such a JiTT-type activity is shown in Figure 5 for Atomic Bonding and can be accessed via the web on Blackboard. This tool acts as a scaffold to illustrate the conceptual framework for a given topical area, as well as a vocabulary-building tool since there are 400 plus terms to learn in a semester. Students become familiar with vocabulary and a conceptual framework by determining which terms fit given blanks. Additionally, the multiple representations of concepts in CCMaps reveal the ways in which various aspects of concepts 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 crystal structures for the concrete real-world items. The figure above shows a steel razor blade with metallic bonding and a nylon parachute with a 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 representations to present them in ways that experts might use in their own visual

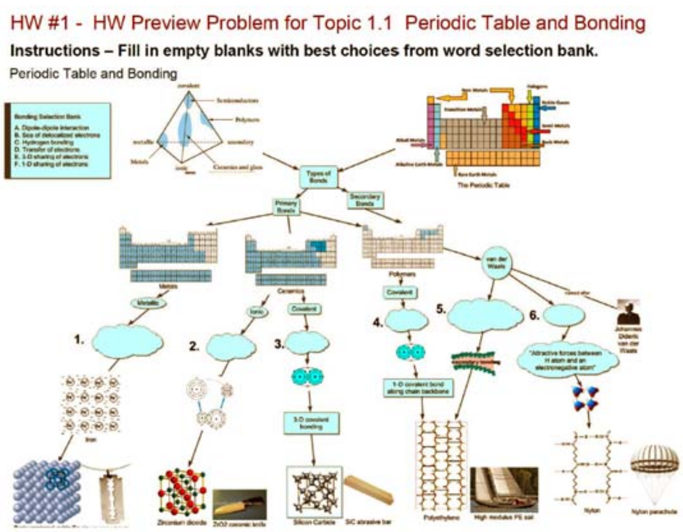

Figure 5. Atomic Bonding Concept-Context Preview Problem

and verbal communication about the topic. Instructors can use these homework results to give feedback to students in the next class. In the exiting survey of a Fall 2012 core materials class, 59% of the 36 students said that CCMaps supported or strongly supported their learning through the Homework Preview Problems.

**Effect of Frequent Formative Feedback on Persistence and Motivation**

In the seven semesters of materials courses taught by the CCLI 1 project with student engagement methods, persistence increased from 85% to 95% compared to six earlier lecture-based classes as in Figure 6. Also, in comparing lecture pedagogy to constructivist instruction, female withdrawal rate decreased from 40% to about 10% for the same classes. These improvements agree with the results of Marrs, Blake, and Gavrin[11]. They found, comparing the lecture-based introductory biology courses to courses taught with JiTT and inquiry activities, those students withdrawing or receiving a D or F dropped from 33% to 18%. 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[12]. 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*)[13] and the degree to which they think that the activity is valuable to their long term future[14, 15]. Fast feedback and concept contextualization improve motivation. Students interested only in the 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. Less motivated students may lose interest and withdraw from a class.

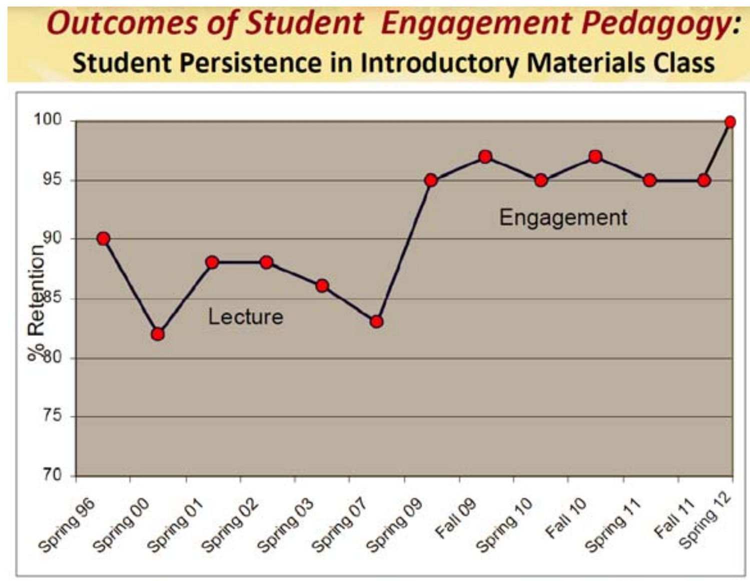


Figure 6. % Retention in Core Material Classes Taught by the PI over time

Motivation can be increased when students who get frequent feedback recognize and identify with a course's relevance, significance, and 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

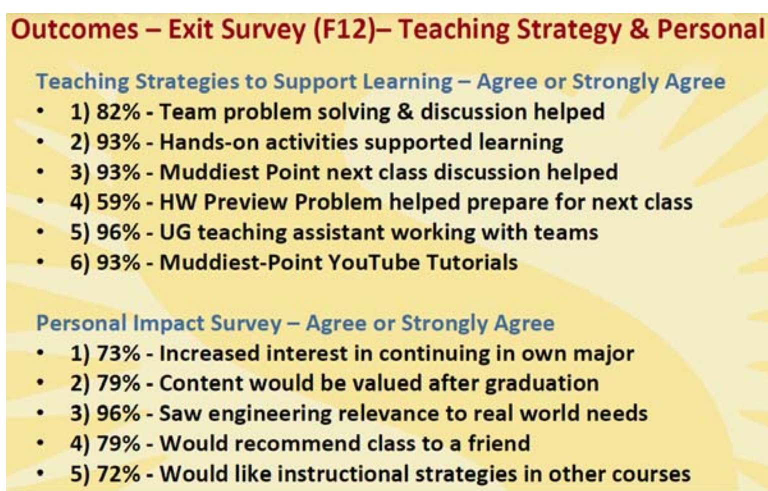


Figure 7. Impact of Formative Feedback on Learning and Attitude

better motivated to learn and continue in engineering. This is directly reflected in the affective portion of the previously cited exit survey for the Fall 2012 core materials class as shown in Figure 7. In particular, results for the first category of responses, the effect of teaching strategies on support of student learning had an average of 86% of students who found that the strategies supported or strongly supported their learning. This category included; team problem solving; hands-on activities; Muddiest Point next-class discussion; peer mentor teaching assistant; and Muddiest Point YouTube Tutorials. In the second category of responses, the personal impact of the strategies on students themselves, the average was 80% who agreed or strongly agreed. This category included the items of: increased interest in their own major; value of content after graduation; saw engineering relevance to real-world needs; would recommend class to a friend; and want instructional strategies to be used in other courses.

**Summary and Conclusions**

In the past, new technologies for teaching and learning have sometimes been a barrier to scaling innovative teaching strategies and materials. In the earlier CCLI 1 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, but the amount of paperwork and reading was cumbersome and has not really been much adapted adaption in engineering education settings. Today, in the JTF project, teaching, learning, and assessment materials have been designed for ease-of-implementation and use with cyber-enabled web tools so that the *JTF* project expands and extends technology functionality beyond JiTT. As such, student assessment results gathered at different time intervals allow the instructor to provide the *fast* frequent formative feedback needed to adjust instruction to address serious learning issues such as robust misconceptions and difficult concepts[2]. For example, in using clicker questions set on the Concept Warehouse platform or on Socrative.com, an instructor can immediately access results of responses and adjust instruction to address learning issues. Thus, student-learning issues in class can be addressed immediately. Cyber-enabled tools with fast and frequent formative feedback discussed here have included: ConcepTests (clicker questions); Daily Reflections, Classroom Activities; Homework Preview Problems; Muddiest Point YouTube Tutorials; and Quizlet.com. Employing such strategies and cyber-enabled tools has simplified instruction and improved student attitude, learning, and persistence.

Future research will study ease of implementation of JTF on cyber-enabled interactive web tools and learning platforms in diverse settings and determine how instructors use assessment results as feedback for adjusting instruction. Also to be studied will be the effect of JTF project on engagement activities and assessments on student learning and attitude to see 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 a positive effect on diverse populations. The broad availability of the web-based JTF materials 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 JTF approach and promote diffusion of its innovations.

The authors of this paper gratefully acknowledge the support of this research by NSF grants #0836041 and #1226325

## References


1. Hattie, J, and Timperly, H., (2007). The Power of Feedback. *Review of Educational Res*., 77 (1), 81–112.
2. Schute, V. J., (2008) Focus on Formative Feedback. *Review of Educational Research*, 78, 153-189.
3. Streveler, R. A., Litzinger, T. A., Miller, R. L., & Steif, P. S. (2008). Learning conceptual knowledge in the engineering sciences: Overview and future research directions. *J. of Engineering Education*, 97(3), 279–294.
4. Vygotsky, L. (1962) *Thought and Language,* T. E. Hanfmann & G. Vaka (Eds.), Cambridge, MA: MIT Press.
5. Donovan, M. S., Bransford, J. D. & Pellegrino, J. W. (Eds.) (1999). *How people learn: Bridging research and practice.* National Academy Press, Washington, DC.
6. Norman, D. (1983) Some observations on mental models. In *Mental Models*, D. Gentner and A. Stevens (Eds.), Hillsdale, NJ, Erlbaum.
7. Gilbert, J. (1995) The role of models and modeling in some narratives in science learning. *1995 Annual Meeting of the American Educational Research Association*, San Francisco, CA.
8. Kelly, J., Graham, A., Eller, A, Baker, D., Tasooji, A., and Krause, S. (2010). Supporting student learning, attitude, and retention through critical class reflections. 2010 ASEE Annual Conference Proceedings.
9. Krause, S., Kelly, J., Triplett, J., Eller, A., and Baker, D. (2010). Uncovering and Addressing Some Common Types of Misconceptions in Introductory Materials Science and Engineering Courses. *Journal of Materials Education*, 32(5- 6), 255-272.
10. Ericsson, K. A., Cramped, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review*, *100*, 363–406.
11. Marrs, K A., Blake, R., & Gavrin. A. (2003). Use of warm up exercises in Just in Time Teaching: Determining students prior knowledge and misconceptions in biology, chemistry, and physics. *Journal of College Science Teaching, 32,* 42-47.
12. Pintrich, P. R., & Schunk, D. H. (2002). *Motivation in education: Theory, research, and practice.* Englewood Cliffs, NJ: Merrill.
13. Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of Educational Res., 66*(4), 543-578.
14. Malka, A., & Covington, M. V. (2005). Perceiving school performance as instrumental to future goal attainment: Effects on graded performance. *Contemporary Educational Psychology, 30*(1), 60-80
15. Wigfield, A. (1993). Why should I learn this? Adolescents' achievement values for different activities. In P. R. Pintrich & M. L. Maehr (Eds.), *Advances in motivation and achievement: Motivation and adolescent development.* (Vol. 8). Greenwich, Conn.: JAI Press.