The Impact of Two-Way Formative Feedback and Web-Enabled Resources on Student Resource Use and Performance in Materials Courses

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The Impact of Two-Way Formative Feedback and Web-Enabled Resources on Student Resource Use and Performance in Materials Courses

Two-way formative feedback has been used extensively in the *JTF* (Just-in-Time-Teaching with Frequent Formative Feedback) project to help instructors understand student thinking and respond with directed feedback and creation of web-enabled student learning resources. When students respond to an open-ended question about issues on content and concepts in a class (e.g. Muddiest Points) their anonymous responses extend beyond the boundaries of the framework an instructor uses to organize, communicate, assess and evaluate their knowledge and understanding. So, if there are hidden issues that impede student learning, such as misconceptions, skill gaps (like charting), difficult concepts, vocabulary ambiguities, etc., the instructor may never become aware of them. In formative feedback students' needs and issues are the defining framework of learning issues, impediments, and barriers that an instructor can address for more effective teaching. Thus, students are empowered to play a role in their learning when they provide input about their instruction. Instructors in the *JTF* project have created a variety of web-enabled tools and resources to address issues revealed by student feedback acquired by using Concept Warehouse or Blackboard survey tools. One tool is "pencasts" in which a smart pen captures a person's writing and/or drawing on a notepad along with audio input to make a "pencast" recording as an audio PDF. These tutorial problem pencasts have been made into videos for the YouTube on the channel *MSEASUproblems*. Another popular student resource is Muddiest Point YouTube videos at www.youtube.com/user/MaterialsConcepts. Another resource is at Quizlet.com, a web-enabled illustrated vocabulary resource at http://quizlet.com/MatSciASU. A final resource is SlideShare.net, a public web site to which slide sets can be uploaded, with an example at http://www.slideshare.net/mseasuslides.

The use of these and other resources, such as textbooks, class notes, course slide sets, etc. has been characterized by a new survey tool called the Student Resource Value Survey (SRVS). The survey was administered four times during a semester before each of four exams. Thus, the research question for this work was, "What is the effect of two-way formative feedback and associated web-enabled resources on student resource use and impact on student performance?" The results of a collaborative of five materials courses at four universities were the following. There was a very positive impact of *JTF* teaching strategies on student attitude, learning, and persistence at all institutions. Student attitude results from a Student Impact Value Survey (SIVS) showed positive results of average 64% for Interest / Attainment Value and high values of 85% average of Utility Value, and also 84% agreeing that the cost of effort was low. Thus, the students have been well motivated through classroom practice using *JTF* pedagogy. The SRVS survey showed resources students used for exam study and problem solving changed across the semester. A few notable trends were, for exam study resource use, teaching assistant went from 25% to 80%, classmates went from 56% to 67%, YouTube Muddiest Point videos went from 47% to 67%, textbook readings went from 28% to 10%, and Google use fluctuated between 42% and 61%. Thus, these results generally show increasing preference to use a peer mentor and classmates as well as electronic resources and decreasing preference to use traditional resources like textbooks. Impact on 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. Overall, the use of two-way formative feedback and *JTF* pedagogy helped guide development of web-enabled student resources as well as shifting students' resource use away from traditional resources like textbooks and more toward peer mentors, classmates and web-enabled resources.

Introduction

JTF (Just-in-Time-Teaching with Interactive Frequent Formative Feedback) is an NSF TUES Type 2 project in which eight faculty at four institutions are using a web-enabled, engagement and feedback pedagogy in their classrooms in the discipline of materials science. In the *JTF* project the guiding principles are based on the research findings described in the book, How People Learn (HPL).[1] It 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) elicit students' prior knowledge to help 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 pedagogy uses two-way formative feedback in which students reflect on their learning in a class with class-end Muddiest Point feedback and instructors respond to student misconceptions and learning issues by adjusting instruction and providing next class feedback to the students. The two-way feedback process promotes self reflection not only on the part of the students, but also on the part of the instructor, who is reflecting on his/her own practice, and taking action in modifying their practice to address student learning issues. This helps shift classroom practice from instructor-centered teaching to student-centered learning. The two-way formative feedback also supports the three HPL principles in the following ways.

The first HPL principle, *eliciting prior knowledge*, can reveal students' misconceptions and learning issues, so an instructor can reflect on the delivery of the content and concepts of that previous class to discern what issues arose in the teaching of the subject matter. The instructor can diagnose what the "knowledge gap" is between content learning objectives and the "gap" in student understanding of the desired knowledge defined by the learning objective. This allows an instructor to pinpoint the origin of the problem, address it in the next class, or create out-of-class learning resources, and close the students' "knowledge gap."[13] Similar approaches have been used in other prior work. Two examples of such methods are formative feedback in Just-in-Time-Teaching[20] and in concept quizzes in Peer Instruction.[19] Similar approaches were adapted to the *JTF* project to adjust instruction and give feedback to students.[13] The second principle, *promoting conceptual change*, is effectively accomplished through "interactive-engagement", in which students engage with one another to construct their own knowledge of subject matter.[5, 6, 23] In the *JTF* project, the student responses in the two-way formative feedback allow an instructor to remodel, reconstruct, and redeliver course content through instruction and creation of classroom engagement activities that address student misconceptions and learning issues.[12] The third principle, *promoting metacognition*, is effective for improving self-reflective learning and motivation[24] and has been implemented by *JTF* faculty through class-end Muddiest Point reflections in which students identify and describe their own learning issues.[3, 7] Such issues are quickly addressed in next class by *JTF* instructors in the two-way formative feedback process.[12] Thus, two-way formative 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 in ways that do more than repeat the original delivery of the material.

So it can be seen that the process of two-way formative feedback affects the three HPL principles by: 1) revealing students' prior knowledge; 2) promoting conceptual change through faculty adjusting instruction and creating student learning resources; and 3) promoting student metacognition through reflection and self regulation. Correspondingly, while two-way formative feedback shifts faculty pedagogy from instructor-centered teaching toward student-centered learning, it can also shift student learning strategies, practices, and resource use from shallow learning with memorization and algorithmic problem solving toward deep learning with deeper conceptual change and greater self-regulated learning. This shift should be reflected in student performance in terms of improving attitude, achievement, and persistence. These characteristics have been assessed and evaluated by faculty participating in the *JTF* project. As such, the research question for this paper is, "What is the effect of two-way formative feedback and associated web-enabled resources on student resource use and impact on student performance?"

Background

In the background section, the objectives of the *JTF* project and approaches used, will first be described and discussed followed by a description of the web-enabled resources available for use by instructors and by students. In the *JTF* project, the project objectives were aligned with the three HPL principles, as well as the types of change that participating faculty would undergo while shifting their pedagogy toward student-centered learning. The background for those objectives is discussed here and the outcomes are discussed in the results section.

For prior knowledge, the first objective was to elicit, identify, and characterize students' misconceptions and learning issues that could impede conceptual change across a semester of learning in an introductory materials course. Methods, tools, and processes were developed for uncovering misconceptions and learning issues. Early data was collected with pencil and paper using: 1) open-ended concept questions in homework, 2) in-class concept quizzes, and 3) end-of-class reflections with students' Muddiest Points.[9] The Muddiest Point data collection was automated last year using either the Concept Warehouse web platform (http://cw.edudiv.org) or the Blackboard survey tool[2, 17] which greatly improved ease-of-implementation of the data collection process. This is now used in the *JTF* project by all eight faculty. This process has catalyzed *JTF* faculty in reflecting on their classroom practice and helping them to shift their pedagogy more toward student-centered learning.

The results of this process were an uncovering of a variety of impediments to conceptual change and learning. These include: student learning issues, such as knowledge gaps on atomic bonding;[13] skill gaps, such as lack of graphing skills and math calculations using log and exponential functions;[12] and underlying origins of different types of misconceptions.[11] Specific misconceptions included: atomic bonding;[10] crystal structures;[14] deformation and processing;[8] and solubility and phase diagrams.[15] These results were used to: adjust instruction; modify materials; create student activities and learning resources; and provide formative feedback to students. In *JTF* faculty are continuing to acquire data to improve their instruction and create new learning materials.[12]

For conceptual change the objective was to develop, modify and implement the misconception-informed and technology-leveraged instructional practices, materials, tools, and resources that engage students to address their misconceptions and learning issues. Three strategies and corresponding actions were used to facilitate conceptual change and achievement. First, instructional strategies, as informed by knowledge of misconceptions, were used to remodel classroom practice, content, activities, homework, and exams.[12] Second, to improve the personal relevance and future value of technical content and concepts for students, real world contexts were integrated into to the publisher's slide sets and contextualized activities were incorporated into each class.[12] Third, new student web-enabled learning resources were created to address misconceptions and student learning issues.[16] As implemented on open websites, they include: 19 YouTube Muddiest Point tutorial videos (Google: *materialsconcepts*); a vocabulary tool (Google: *matsciasu*) with 500+ terms for 22 topics; the slide sets used in the YouTube tutorials (Google: *mseasuslides*); and solved example problems in materials science on YouTube (Google: *mseasuproblems*).

For metacognition the objective was to assess the impact of student reflections on their learning through misconception-informed feedback, instruction, and materials on student conceptual change and learning along a materials learning progression. To accomplish this, web-enabled formative and summative assessment tools were used to acquire, analyze and understand students' misconceptions and learning issues and the strategies they used to address them. The main means of acquiring the information was from student reflections and pre-post topical concept quizzes. Once underlying misconceptions and learning issues were uncovered, teaching strategies and content were adjusted to accommodate and resolve those issues. Also, as previously discussed, a number of student learning resources were created based on knowledge of the student issues, such as the Muddiest Point YouTube videos and the web vocabulary site. The results, with respect to impact of the reflective practice, modified materials, and web resources, were assessed for student attitude, achievement and persistence.

For faculty change, the objective of characterizing the extent of faculty shift toward student-centered teaching beliefs and classroom practice and use of web-enabled teaching and feedback tools, quantitative and qualitative surveys have been conducted throughout the three-year long project. These outcomes are reported in the results section.

For web-enabled faculty tools and resources, new and improved teaching and learning tools have been implemented into a web environment which include Concept Warehouse and the Blackboard learning platform that is available at most institutions. In particular, two instructor Just-in-Time-Teaching tools were web-enabled on an automated assessment site Concept Warehouse (CW) at http://cw.edudiv.org. One is the end-of-class, Muddiest Point Student Reflections, which was web-enabled for easy, automated data collection and reporting. The tool also includes a built-in Word Cloud feature for a quick analysis of the most significant Muddiest Points for a given class from word size which is proportional to word frequency use as found in student responses. The automated Muddy Point data collection and analysis and easy-to-read PDF output has encouraged greater faculty participation for diagnosing student learning issues and adjusting instruction to address them. Features for setting times and dates of data collection now include advanced settings for an entire semester with: dates for administration, start and stop times, and notifying students start, stop, and deadline reminders. Output is automated and includes: a PDF of all comments and intensity ratings (1-5); an excel spreadsheet with all responses; and a word cloud. This information for the instructor is available from the CW site, which also permanently stores all responses generated. A second tool available on CW is a web-enabled collection of over 200 materials-related Conceptest question sets used for classroom clicker questions or pre-post topic concept quizzes, both of which are now easier to use via the web, which can increase usage. This set of materials science concept questions is but a small part of over 2000 questions targeted toward five chemical engineering core classes. Such concept quizzes are used to reveal student misconceptions as well as assess effectiveness of instruction.

For web-enabled student learning resources, four complementary web-enabled resources were developed and implemented over the past three years. The use by students of these and other resources was assessed by a new assessment tool, the Student Resource Value Survey (SRVS), to gain insight into the strategies that students use to prepare for exams and learn and use concepts for problem solving activities. One web resource is a set of 21 Muddiest Point YouTube tutorial screencasts videos located at the Google keyword: *materialsconcepts*. During the 30 months of video development and site use, it has received over 300,000 views and acquired over 2,000 subscribers. These videos provide fast feedback and self-tutoring to help students address their own learning needs and issues. Their use and potential to improve content and concept understanding is due, in part, to the fact that their content focuses on a given topic's Muddiest Point responses generated by students themselves. The basis for a video's usefulness is that it is directed toward addressing student misconceptions and difficult concepts by decomposing them into fundamental concepts. They are explained and illustrated in straightforward student speak with few assumptions made about students' prior knowledge or proficiency in necessary skills required to understand target concepts or related problems. Additionally, videos have potential to impart far more knowledge than lecture and note taking. While a typical instructor speaks at a rate of 2 to 3 words per second, students write at a rate of 0.2 to 0.3 of a word per second. Thus 90% of what an instructor says is not captured in students' notes, but this may be somewhat compensated by students' audio learning. On the other hand, the Muddiest Point videos target student learning issues and, with students' option to rewind and replay portions of video content they struggle with, they can then master that content and move forward without being lost because of a small, but difficult, portion of the content. When students feel they are able to not just understand the material, but truly self regulate to control and master it, their self-efficacy and motivation improve, as well as persistence on a particular task, to the point of achieving success.[4] The extent to which this resource impacts student learning shows that it is used increasingly by up to 70% of students across a semester. This will be discussed further in the results section.

A second student resource is the Materials Vocabulary Building Resource site located on the open access vocabulary site of Quizlet.com where the materials science vocabulary can be accessed at Google keyword: *MatSciASU*. The site contains over 500 materials science terms sorted into the 24 topics and subtopics covered in a semester-long materials class. The Quizlet.com resource and tool set has capabilities to present a given term/definition/image in the form of visual vocabulary e-flash cards or e-vocabulary games. The games include "Scatter", where 8-10 terms and definitions are scattered randomly on the screen and, when the cursor is used to drag a word over the proper definition, it will vanish. There is also a timer to see how much time it takes to make all terms and definitions disappear. This gives this activity the sense of being a game, and not strictly a vocabulary exercise. It also has three Word Quizzes – Multiple Choice, True-False, and Fill-in-the-Blank. An example of a typical electronic definition card has both term and definition present on the same side. Another option puts the term on one side and the definition on the other side of an electronic flash card. The extent to which this resource impacts student learning shows that it is used on the average of about 30% of students across a semester. This will be discussed further in the results section.

A third resource contains slide sets for each Muddiest Point video is located at Google keyword: *MSEASUslides*. These YouTube slide sets have been viewed over 7000 times and can be downloaded so students can make notes while watching Muddiest Point YouTube videos. Instructors at collaborating institutions want to build a community of practice so resources like this could be shared by all. A fourth resource is a growing set of solved example problems that is located on a YouTube channel accessed from the Google keyword: *MSEASUproblems*. These four complementary student Just-in-Time-Learning web resources to help students close their knowledge gaps and achieve their learning goals in the process of actively constructing their own knowledge. In this model, students interact with content from diverse resources, including social engagement and the web, and connect with prior knowledge to build a conceptual framework of retrievable knowledge which can be applied and new and different situations.

Results and Discussion

Student Resource Value Survey (SRVS): In order to gain insight into students' learning strategies, the extent to which students used different resources available to them was assessed, including web-enabled resources. To do so, a new assessment tool was created to measure the frequency with which students use different resources to prepare for exams, the Student Resource Value Survey (SRVS). It is shown in Table 1-1 for preparing for exams and Table 1-2 for resolving confusing concepts in problem solving. The table below shows the categories that are covered for a single instructor's course. There are core resources that are applicable to all *JTF* instructors, but there are custom resources used by a given instructor added to the survey.

Table 1-1. Resource use for exam preparation and 1-2. Resource use for problem solving.

1. How often did you use the following resources to help you study for your exam? (% = frequently or always)	Sp 14 Exam 1	Sp 14 Exam 2	Sp 14 Exam 3	Sp 14 Final Exam	Sp 15 Start Male	Sp 15 Start Female
a) your own classroom notes	86%	92%	87%	97%	81%	92%
b) homework problems	81%	74%	61%	50%	51%	54%
c) posted lecture slides	72%	74%	92%	93%	67%	54%
d) old exams or quizzes	78%	79%	95%	87%	74%	100%
e) textbook readings	28%	16%	21%	10%	41%	15%
f) classmates/friends	56%	58%	61%	67%	74%	46%
g) instructor	25%	24%	39%	43%	37%	8%
h) teaching assistant	25%	45%	76%	80%	4%	8%
i) tutoring service	25%	8%	8%	17%	8%	0%
j) exam review session	53%	79%	82%	83%	-	-
k) in class muddiest point responses	28%	34%	32%	70%	-	-
l) youtube muddiest point videos	47%	42%	68%	67%	-	-
m) quizlet.com e-vocab. flashcards	33%	32%	24%	30%	-	-
n) slideshare.com slide sets	14%	8%	13%	13%	-	-
o) google	61%	42%	47%	57%	81%	69%
p) other	17%	3%	5%	7%	-	-
2. Which resources do you use when you encounter a confusing concept in problem solving? (% = frequently or always)	**Exam 1**	**Exam 2**	**Exam 3**	**Final Exam**	**Sp 15 Start Male**	**Sp 15 Start Female**
a) your own classroom notes	81%	89%	89%	90%	81%	85%
b) homework problems	56%	58%	55%	43%	63%	77%
c) posted lecture slides	72%	76%	82%	83%	70%	77%
d) old exams or quizzes	42%	47%	63%	55%	41%	46%
e) textbook readings	58%	39%	37%	30%	52%	46%
f) classmates/friends	69%	61%	63%	55%	70%	85%
g) instructor	25%	18%	39%	43%	41%	15%
h) teaching assistant	44%	42%	71%	73%	8%	15%
i) tutoring service	19%	3%	11%	10%	11%	0%
j) exam review session	36%	53%	74%	72%	-	-
k) in class muddiest point responses	44%	32%	39%	70%	-	-
l) youtube muddiest point videos	53%	61%	66%	70%	-	-
m) quizlet.com e-vocab. flashcards	42%	21%	18%	17%	-	-
n) slideshare.com slide sets	14%	13%	13%	7%	-	-
o) google	81%	55%	58%	67%	85%	77%
p) other	14%	5%	5%	7%	-	-

In order to become a more effective instructor, it was thought that developing a resource survey would show which resources students valued most, so that those could be expanded and refined, while little used resources could be deemphasized. Table 1 shows for the Spring 2014 term in the first four columns, a set of responses over 4 exams, of 34 to 37 students in a materials class. In columns 5 and 6 are shown, for the Spring 2015 term, the semester-beginning results for 42 students (29 male and 13 female) based on how they prepared for exams and solved problems in prior courses. Students responded to the general questions of, “How often did you use the following resources to study for your exam?" in Table 1-1 and "How often did you use the following resources address confusing concepts in your problem solving?" in Table 1-2. There was a Likert scale rated 1-4 with 1 being never, 2 being sometimes, 3 being frequently, and 4 being always. The table shows per cent of students that responded to a resource use with value of 3 *frequently* or 4 *always*. The survey was given in the class preceding each of four hourly exams in Spring 2014 or at semester beginning in Spring 2015. The items of a) though j) represent standard resources likely to be used in many engineering classrooms and might be considered as “standard” resources, while items k) through p) are non-standard or “custom” resources that are particular to a given instructor's classroom. Some observations and trends will now be discussed.

With respect to Table 1-1, exam resources used, a few general questions posed were: to what extent do students use traditional resources, such as a textbook; to what extent do students use web-based resources; and, do students shift resource use as a result of the *JTF* web-enabled, engagement and feedback pedagogy? Data from Table 1-1 showed the following. The most heavily used resource for Spring 2014 was a), the class notes, from 86% to 92%, which were modified publisher slide sets copied and distributed in every class, with a number of slides having activities or fill-in the-blank spaces. Homework problems, b), were used less to prepare for exams, decreasing from 81% to 50%, possibly due to increasing use of exam reviews j), which increased from 53% to 83%. Posted lecture slide set use, c), increased across the semester from 72% to 93%, possibly due to the fact that solutions to class engagement activities and homework problems were included. Somewhat surprisingly, the publisher’s textbook, e), was among the least used resource and use decreased across the semester from 28% to 10%. So it may be that students, instead of preparing for exams by the textbook, used the modified engagement class slide set notes and attended the exam review sessions. Web resources received moderate and increasing use across the semester. Muddiest Point YouTube videos, l), increased in use from exam 1 to 4 from 47% to 67% and the e-vocabulary site, m), varied in use, from 33% to 24%. Google use, o), from exam 1 to 4, was moderately high, and ranged from 42% to 61%.

Comparing the results of the Spring 2014 four-exam set to the Spring 2015 semester-start results showed some differences. For exam preparation Spring 2014 compared to Spring 2015, the results showed the following. Resource use did not differ greatly for a) classroom notes, b) homework problems, c) lecture slides, and d) old exams. While average textbook use, e), did not differ much between 2014 and 2015, interestingly, 2015 males used textbooks to prepare for exams much more than females, 41% to 15%. Google use for the 2014 class, at an average of 52%, was considerably lower than the 2015 class, with a value at 75% average.

In terms of exam preparation with respect to personal interactions there was, for the 2014 exam set, significantly increasing use of the teaching assistant, h), from exam 1 to 4 from 25% to 80%, along with similar increasing use in exam reviews, j), from 53% to 83%. Clearly, the teaching assistant changed students' study strategies, which was also reflected in one instructor's students' exam performance, with well more than half of the class receiving A or B on all tests. It might also be noted that, from exam 1 to 4, students use of classmate/friends, f), moderately increased from 56% to 67%, which shows considerable interactions between students when studying for exams, which is likely beneficial. The final note is that, from exam 1 to 4, use of instructor as a resource, g), increased moderately from 25% to 46%. This may correspond to the instructor providing more detailed graphical Muddy Point responses during the time between exams 2 and 4. For classmates/friends, f), as a resource, the average was similar for 2014 and 2015. However, for classmates/friends, f), in 2015 males were higher than females by 74% to 46%, but the opposite was true for resource use in solving problems in Table 1-2, where males were lower than females by 70% to 85%. So, for the 2015 class semester start, females had worked with classmates much more than males in solving homework problems, while males had worked much more with classmates in preparing for exams. Comparing the 2014 and 2015 results for using the instructor, g), as a resource, the average was similar. However, for 2015, there was a significant difference in using instructors as a resource, with males at 37% compared to females at 8%. Similarly in Table 1-2 for resource using in solving problems, there was a similar trend for using instructors as a resource with males at 41% and females at 15%. So there may be a gender issue in students having interacted with their instructors which appeared to be inhibited for females. The reasons are uncertain, but the literature has discussed the issue of the "chilly climate" for females in engineering classes, which may be a factor.

Trends in resource level usage for Spring 2014, for confusing concepts in solving problems in Table 1-2, were generally similar to values for the studying for exams, except that textbook usage, e), was about double that of exam preparation, but did decrease from 58% to 37% from exam 1 to 4. This may show that students did value the text when first learning the material and solving problems, but as the semester wore on, they shifted their learning strategies and resource use more to e-resources and personal-interactions, and especially so to the teaching assistant. Comparing the 2014 and 2015 resource use for problem solving results are generally similar except for use of teaching assistant, g), which is much less for the Spring 2015 students 12% average than for Spring 2014 students at the first exam, which was 44%. This indicates that for the 2014 students the teaching assistant, who worked with students in class during engagement activities and out-of-class with office hours had, by the first exams in 2014, become a valuable learning resource for the students.

So, overall for 2014 students, it can be seen that web use became an increasingly important resource, both for studying for exams and for solving problems. This was shown for use of Google, o), Muddiest Point videos, l), and quizlet.com vocabulary flash cards, m). For the 2015 semester start students, their heavier use of Google, o), indicates that a similar trend may prevail. Another trend for 2014 students is the decreasing use of the textbook across the semester, both for exam study and for problem solving. Finally, the most striking change over time is the dramatic increase in use of the teaching assistant and associated exam reviews from exam 1 to 4. One overall significant result is that the different types of resources students use for exam study and problem solving is not static over time, but does change significantly as a result of the web-enabled, engagement and feedback pedagogy. Whether students shift their learning strategies and resource use in traditional, lecture-based courses would be an interesting question to explore.

Student Impact Value Survey (SIVS): In order to explore student attitude with respect to motivation factors of interest, usefulness, efficacy, personal cost for *JTF* pedagogy a semester-end survey was created based on expectancy/value theory. The survey was given to five classes at 4 institutions with all having similar levels of very positive results discussed here in Table 2. The results were analyzed with respect to three major factors: interest/attainment value; utility value, and cost. The data show the impact on student attitude of *JTF* teaching strategies with respect to students' Muddiest Point Reflections in the two-way formative feedback process.

Table 2. Student Value Impact Survey (SIVS) on impact of Muddiest Point Reflections

n (instructors) = 4 and n (students) =140

INTEREST/ATTAINMENT VALUE	Agree	Disagree
motivated me to do well in the course	59%	41%
was an effective way to increase engagement	79%	20%
helped me better understand my own learning	69%	31%
increased my level of responsibility	59%	41%

UTILITY VALUE	Agree	Disagree
will be of value after graduation	81%	19%
was useful in career and/or graduate school goals	79%	21%
helped me see relevance of eng to the real word	87%	13%
helped me learn importance of mat science to engineering	93%	7%
helped me learn importance of manufacturing to engineering	88%	12%

COST	Agree	Disagree
required too much effort	17%	83%
made me frustrated and anxious	14%	86%
required too much time	15%	85%

For *interest or intrinsic value*, it refers to an individual's anticipated enjoyment of engaging in a particular activity. Related to interest value is attainment value or an individual's perception of how the activity contributes to the conception of who he or she is fundamentally. The two-way formative feedback was found to be motivating by 59% of the students who agreed or strongly agreed. Then 79% of students said it increased their engagement which suggests that they were paying more attention in class because they were thinking about. One student from a Spring 2013 class said that Muddiest Points "Helped me reflect on what I enjoyed and understood well from the lecture." Also, 69% said that it helped them better understand their own learning, which was reflected in the quote, "It helped me recognize what I didn't know or understand." Finally, 59% agreed that it increased their level of responsibility. The results indicate that a significant majority of students found that two-way formative feedback resulted in a positive attitude toward the class content and how it related to themselves.

For *utility value*, it refers to an individual's perception of the advantages that result from engaging in the task of two–way formative feedback for their future goals and rewards. This translates into motivation, which can be increased when students recognize and identify with a concept's relevance, significance, and possible value to their own future. 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 utility portion of the SIVS survey. Between 79% and 93% agreed or strongly agreed that the class and two-way formative feedback: would be of value after graduation (81%); would be useful in career and graduate school goals (79%); helped them see the relevance of engineering to the real world (87%); help them learn of the importance of materials science to engineering

(93%); and helped them learn the importance of manufacturing to engineering (88%). One student said that the reflections helped him because "Relating things to my daily life helped me to retain information better." The results for utility or usefulness showed that students strongly felt that found the material learned in their course to be of value to them in their current and future endeavors as learners and professionals.

For *cost*, it represents an individual’s perception of sacrifices required, including effort, time, and psychological impact, for successful impact of an activity. Results show that 83% to 85% of students felt that the Muddiest Point reflections did not take too much time or effort nor were they a frustrating activity.

Overall, the results on students' attitude on use of muddiest point reflections and the two-way formative feedback process has had a very positive impact. For instructors it is a means of having major impact on the delivery of course content. The benefit to such two-way formative feedback is the associated gain for both instructors and students. The two-way feedback provides a way for students and instructors to have a dialogue between one another, which in turn restructures the role of the teacher as “performer” to teacher as “coach”. This role shift allows students to voice their opinions as a means to impact course content delivery. Instructors can then use student input to adjust instruction and create learning resources to fit student needs.

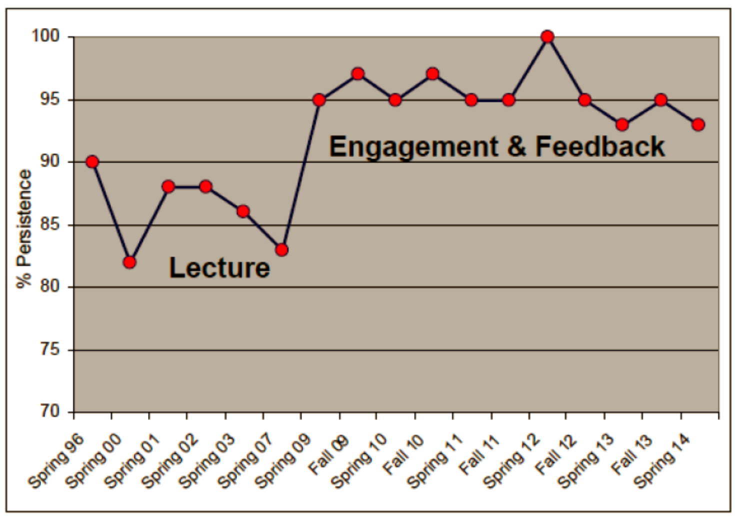

Figure 1. Persistence over time for lecture versus engagement pedagogy in a materials course.

Two-way formative feedback can also impact student performance in terms of class persistence and student achievement. Use of two-way formative feedback to create associated web-enabled resources are critical for facilitating self-efficacy and self-regulated learning. This 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. Once underlying misconceptions and learning issues are uncovered, teaching strategies and content are adjusted to accommodate those issues, as well as opportunities to create new student learning resources based on knowledge of the student issues. Such resources, previously discussed, include the Muddiest Point YouTube videos, the Quizlet.com web vocabulary site, the Slideshare.org slide sets of Muddiest Point videos, and the new set of materials science example problems on the YouTube site, *mseasuproblems*. The overall impact of the *JTF* web-enabled, engagement and feedback pedagogy on student class persistence is shown one *JTF* instructor's class in Fig. 1 (# 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.[22] 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*)[21] and the degree to which they think that the activity is valuable to their long term future.[18, 25] 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.

Another measure of achievement was the change in final exam mean score for the one instructor's materials class over time, as shown in Figure 2. It shows an upward shift of final exam mean from 69% in Fall 2009 to 75% in Fall 2011 to 79% in Fall of 2013. That represents a shift of a full letter grade over four years, which reflects the increasingly effective implementation of the innovative pedagogy, as well as new student learning resources, and experience in teaching with engagement. Another instructor reported that, over 3 classes, the % of females in a materials class receiving A's or B's increased from 34% to 65% when student reflections on interesting and muddiest points were used. Similar strategies were used in *JTF* for supporting *JTF* faculty while implementing the strategies in their own classrooms.

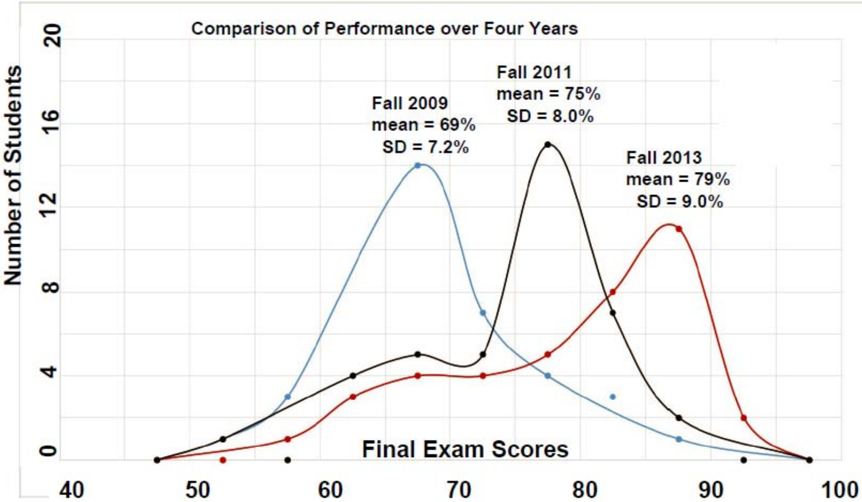

Figure 2. Final exam grade distribution for F09, F11, and F13

Faculty in the *JTF* project also felt that the web-enabled engagement and feedback pedagogy has had a positive impact on the students in their classes with respect to their attitude, achievement and persistence. Their responses to a November 2014 survey to the question, "What is the evidence that the student engagement strategies in classes are effective?" The responses are shown below. The results are the evidence that show the impact of the JTF web-enabled, engagement and feedback pedagogy on student performance through faculty implementing the three HPL principles in their classes by shifting their pedagogy toward student-centered learning.

- Many fewer students with D, E, or W and significant improvement in hourly exams and final exam. Over four years the mean on the final shifted one full grade from C to B.
- I chose 5 as I am not currently teaching. So NA.
- Surveys show that attitude is high. In the middle of determining if achievement is improved.
- The evidence are the comments from students and their persistence in the class.
- Grades are up, student retention is up and students are participating and engaged in class discussions.
- The only indicator that I believe I have is the change in depth to the student responses. They seem to be utilizing what I am providing them with to enhance their responses. I haven't collected any data to get a better sense of if my efforts are effective.
- More students are doing better in the assignments and exams this semester compared to previous ones.

Summary and Conclusions

This paper showed the value and use of the Muddiest Point two-way formative feedback process which consists of: 1) acquiring data from students reflecting the content and experience of each class across a semester; 2) how instructors can assess and characterize student responses in order to diagnose the learning issues that can impede students from achieving their learning goals; and 3) how instructors can provide rapid feedback to students and create valuable web-enabled student learning resources. The quick web-enabled communication between students' feedback and information and the instructor's responses to give feedback, adjust instruction, and create of web-based learning resources can enhance students' progress toward their learning goals. One feedback method cited next-class feedback slide or two for discussion at the beginning of the next class which can help clarify confusing or difficult-to-grasp concepts. Another method shown was to create Muddiest Point YouTube tutorial screencasts, such as the ones at Google keyword: materialsconcepts, which could be viewed by students to help resolve difficult concepts and also assist in solving homework problems. Positive impact on student achievement Muddiest Point and engagement pedagogy showed final exam grade shift of a full grade over a four year interval, as well as improving achievement by females in another class using Muddiest Point reflections.. A high value of persistence was shown from 95% to 97% over two semesters for a cohort of *JTF* faculty. Positive student attitude was shown from the results of the SIVS survey and the shift of students toward use of more web-enabled resources was shown from the SRVS survey. Overall, this paper showed the very positive potential impact of incorporating two-way formative feedback and web-enabled student learning resources in strategies in teaching and learning for positive gains for student attitude, achievement and persistence.

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