AC 2010-1152: SUPPORTING STUDENT LEARNING, ATTITUDE AND RETENTION THROUGH CRITICAL CLASS REFLECTIONS

Jacquelyn Kelly, Arizona State University

Jacquelyn Kelly, Arizona State University Jacquelyn Kelley has an M.S. in Materials Science and is a Ph.D. student in the College of Education at Arizona State University. Her BS degree is in Physics and Chemistry. Her principle research areas are inquiry-based learning and development and assessment of inquiry-based modules in materials science and engineering. She teaches physics, chemistry and mathematics in a local arts high school.

Aaron Graham, Arizona State University

Aaron Graham, Arizona State University Aaron Graham is an undergraduate at Arizona State University in the School of Materials at Arizona State University. He has a B.S. in Psychology and is working toward his BS in Materials Science and Engineering after which he will work in industry. He has been working as an undergraduate teaching assistant in the Introductory Materials course for the past half year.

Andrea Eller, Arizona State University

Andrea Eller, Arizona State University Andrea Eller is an undergraduate major in Materials Science and Engineering at Arizona State University. She has been working as an undergraduate research assistant for the past year in the area of engineering education.

Dale Baker, Arizona State University

Dale Baker, Arizona State University Dale R. Baker is a Professor of Science Education in the Department of Curriculum and Instruction at ASU and is the Co-Editor of The Journal of Research in Science Teaching. She teaches courses in science curricula, teaching and learning, and assessment courses with an emphasis on constructivist theory and issues of equity. Her research focuses on issues of gender, science, and science teaching. She has won two awards for her research in these areas. In this work she is responsible for developing assessments and overseeing data collection, analysis, and feedback to the project.

Amaneh Tasooji, Arizona State University

Amaneh Tasooji, Arizona State University Amaneh Tasooji is an Associate Research Professor in the School of Materials at ASU and has been teaching and developing new content for materials science and engineering classes and laboratories. She has developed new content and contextual teaching methods from her experience as a researcher and General Manager at Honeywell Inc. She is currently working to develop new assessments to reveal and address student misconceptions in introductory materials engineering classes.

Stephen Krause, Arizona State University

Stephen Krause, Arizona State University Stephen 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, design and selection of materials, general materials engineering, polymer science, and characterization of materials. His research interests are in innovative education in engineering and K-12 engineering outreach. He worked on Project Pathways, an NSF supported Math Science Partnership, in developing modules for Physics and Chemistry and also a course on Engineering Capstone Design. He has also co-developed a Materials Concept Inventory for assessing fundamental knowledge of students in introductory materials engineering classes. He is currently working on NSF projects to develop a learning trajectory for macro-micro concepts in materials science education as well as materials science modules which integrate interventions for student misconceptions using a 5E (engage, explore, explain, extend, evaluate) pedagogy with technological tools of Just-in-Time-Teaching and

Classroom Clicker questions.

Supporting Student Learning, Attitude, and Retention Through Critical Class Reflections

Abstract

Students may have preformed ideas about learning and the role of the student and the instructor in the classroom. These types of misconceptions may impede student learning just as topical misconceptions do. In this research, we redefine the role of student and instructor, as well as how students can reflect on their progress in learning. They are informed of the need for their shifting of self image from dependent passive learner in the classroom to an independent, well-spoken, reflective learner. In doing so, learning, attitude, and student retention can be improved. Overall, daily reflections provide formative feedback to the instructor and allow reflection on teaching and pedagogy. Students can self regulate, or monitor their learning. Students can reflect on their role in class see they are active participants in their learning. We report here on the research question of, "How can we use class reflections to support student learning, attitude, and retention?" Assessment of the Class Reflection Points through emergent themes coding indicates that responses to the Most Interesting Point show students' quite active engagement in content, activities, and team member interactions. The Muddiest Point shows confusion, uncertainty, or lack of self efficacy on sometimes a narrow content slice, sometimes scattered concepts of confusion, and sometimes no muddiest point at all. The instructor is frequently surprised that his perception of his clarity of content concept and presentation that do not always align with student comments. Analysis of the Take Away Point indicates responses are strongly content focused and need to be broadened to better reflect self awareness of as value of class to their own learning, future impact of knowledge and skills, communication effectiveness, and other important affective skills. It was found that by utilizing the Classroom Reflection Points, students learning was supported, students felt their learning was supported, student attitude was raised, and percentage of student retention increased. Details of student comments, analysis and conclusions will be described and presented in the paper.

Introduction

Class reflection points are not frequently used in engineering courses. Documenting reflective thoughts are more often recorded in diaries or journals for liberal arts and science courses. The reflections are normally about a specific topic and are simply assignments. However, these critical class reflection points are designed to provide formative feedback for the instructor allowing adjustments in teaching and pedagogy to be made specifically for a class. Using critical class reflection points can also help the student to understand their role as students, create a more positive learning attitude and increase retention of students. Self-efficacy of students can increase because the class is designed so that the new information is being based on their prior knowledge which they should already feel confident with and motivate them to learn. The critical class reflections provide a clear easy way to track the attitudes, understanding, and learning methods of the students in the class.

The goal of this research is aimed at answering the question, "How can we use class reflections to support student learning, attitude, and retention?" We purpose that by asking students questions after each class period about what interests them, what they find confusing, as well as

what they find most valuable we will be able to discover any misconceptions or concepts that students are having difficulty with. We can then address and correct the difficulties briefly in the next class. This will help the students feel more confident about that topic and allow them to move on to the next topic with a more positive attitude. When we ask the students about what they find interesting the students are more likely to remember the parts of the topic that they enjoyed and the instructor will be able to better relate to their students and identify what the students find fascinating. By having the students reflect on what information they found most valuable, they are determining what information will be beneficial for them to know in the future and motivate them to think about the topic more in depth.

Background

Motivation and Value in Learning

Motivation is an important factor supporting students' learning. Student's choices, persistence, and effort in learning contexts both independently and in groups are affected by their motivational and affective beliefs[1]. Self efficacy, or students' believes about their abilities, and the value they see in learning effect their motivation[2,3,4]. Value is increased when students can identify the role of content in their personal futures[5]. When students are motivated by a grade rather than the value of content, learning techniques utilized will resemble short term recall rather than conceptual understanding[6]. One strategy to promote conceptual learning was proposed by Bandura. He suggested that social interactions could improve both self efficacy and perceived value of content.[7]

Self Efficacy

Students' confidence in their abilities can determine how much effort and what types of learning strategies are employed. Bandura examined this topic in depth. He formulated a theory that outlines how self efficacy changes and how it impacts student learning and cognition.

Bandura's Theory of Self-Efficacy

In an account of Bandura's Theory, Yasar explained that self-efficacy theory predicts success as a result of perseverance among those with high self-efficacy[8]. She identifies four sources if self-efficacy as described by Bandura: enactive mastery experience, vicarious experience, verbal or social persuasion, and physiological and affective reaction. Enactive mastery experiences are those which a student experiences success. These types of experiences influence self-efficacy because students create judgments of their own abilities based on actual experiences[9]. Mastery experiences provide a realistic judgment of one's future performance because these experiences are based on the actual successes or failures of the learner[9]. Vicarious experiences are experiences that a student has by observing someone else complete a task. Vicarious experiences support learning because confidence can be gained by noting reasons a task was either completed correctly or not. Social persuasions are positive acknowledgments by members of a social group. This positive feedback can act as positive reinforcement for perseverance. The fourth source of self-efficacy is physiological and affective reaction. These reactions are emotional responses that occur prior to cognition and can influence self-efficacy of a particular task. Each

of these four sources of self-efficacy can impact a student's confidence level in a particular task or content area. As a result, it is useful to monitor each to ensure that students maintain a level of self-efficacy necessary for success in class. Student reflections can be used as a tool to elicit sources and level of student self-efficacy.

Reflections

Stamper describes reflections as being an extended thought processes that builds relationships between prior knowledge and recent experience[10]. In bridging these ideas, he argues, that students can work towards a more coherent and connected conceptual framework. But not all acts of reflection are equal or achieve the same ends. For example, written reflections are more effective than those explained aloud[10]. It may be that written reflections allow additional means for students to interpret thoughts and understanding. Also, just as students learn in unique ways, students also may reflect in unique ways. This was confirmed by May and Etkina[11]. Subek and Eunhve described three "levels" of reflection with each requiring greater levels of cognitive demand than the previous. The three levels described were reacting (a reflection primarily of feelings towards classroom experiences), elaborating (connecting those feelings to prior knowledge), and contemplating (where students reflect about *how* they are learning)[12].

Smith & Hatton, found that when two or more people engage in conversation with questioning or confronting helps the reflective process by allowing self-revelation to take place in a safe environment[13]. This self reflection occurs as team members share ideas. In discussion, strengths and weaknesses of ideas are noticed and students are able to internally self reflect. It is after this internal reflection that a student might be able to effectively complete a written reflection.

Methods

The primary purpose of this study is to understand the effect of frequent written student reflections. To do so, we ask the question, "How can we use class reflections to support student learning, attitude, and retention?"

Participants

Participation in this study was voluntary, though assessment was discussed and primarily collected during the course of a regular class. Participants in this research were from a sample of 38 students enrolled in a 2009 semester of an introductory materials science and engineering course. Of the 40 students initially enrolled, only 38 were selected due to students withdrawing early from the course. Of the 38 students who remained enrolled in the course, all students were engineering majors with 13 (34.21%) chemical engineers, 9 (23.68%) mechanical and aerospace engineers, 8 (21.05%) industrial engineers, 7 (18.42%) materials science engineers, and 1 (2.63%) bioengineer. There were 9 (23.68%) females and 29 (76.32%) males. Six students representative of general class trends were chosen to evaluate in depth.

Teaching Methods and Interventions

The introductory course in which the sample was drawn was a 15-week semester course required for most engineering majors meeting for seventy-five minutes two times per week. The course

was taught by a professor with a Ph.D. in engineering and 28 years teaching experience. Throughout instruction students were asked to frequently express their mental models in multiple modes in addition to the multimodal assessment tool. Student expressions and explanations of thinking took place in different ways, or representations, including written, verbal, diagrammatical, mathematical, graphical and, kinesthetic. Following each class period students were asked to create a reflection, which is discussed below. By having students explain their ideas in each of these modes at various times throughout the course of instruction, frequent multimodal expressions of ideas were consistent throughout the entire course.

Measures

Topical Module Assessments

To obtain specific information about student conceptions, open ended pre and post Topical Module Assessments were created. In order to develop the assessments, common misconceptions were reviewed from the literature, past research, the Materials Concept Inventory, and experiences from prior sections of the introductory materials science and engineering course. These assessments required students to respond to questions using multiple representations. These multiple representations, or modes of expression, included written descriptions, concept sketches, and diagrammatical representations. The Bonding Module Assessment incorporated concept sketching and written descriptions of bond types as well as identification of bond type and important properties of common household items. The Crystal Structures Module Assessment asked students to sketch locations of atomic on various planes of body centered and face centered cubic unit cells. The Deformation Module Assessment asked students to describe what occurred during deformation of different types of materials and accompany their description with a sketch. The Polymer Module Assessment asked students to describe and sketch the internal atomic structure and describe and sketch what occurs during deformation. The Electrical Properties Module Assessment asked students to predict changes in conductivity resulting from changes in the material and to support their answers with a sketch. The assessments were graded for conceptual understanding.

Quantitatively, on each question, each student had the opportunity to score a maximum of two points. Any answer that was correct was awarded two points, an answer that was partially correct but may have had some incorrect ideas was awarded one point, and an answer that was blank, completely incorrect, or non-relevant was not awarded any points. This rubric allowed for achieving a maximum nonzero score, different for each assessment, and a minimum score of 0. A paired samples *t*-test was conducted in order to assess significance in gains. This allowed for an understanding of the change in student conceptual frameworks and provided evidence to support quantitative conceptual change.

Qualitatively, each written response on each Topical Module Assessment was read and any misconceptions present were made note of. It was possible, and often occurred, that there were multiple misconceptions for each student's response to each question. After reading through and making note of student misconceptions, like misconceptions were grouped into categories. These categories were developed through emergent themes from student misconceptions as displayed on each Topical Module Assessment. For example, many student misconceptions of crystal

structure included addition or deletion of atoms in the unit cell. Not all misconceptions involved adding or removing the same atom, but because these were similar misconceptions, hinting at an emergent theme, they were grouped into one category referencing extra or missing atom(s). Each student conception was then assigned categories based on these emergent themes. This process continued for each student response to each question on each Topical Module Assessment. The categorization with emergent themes gave categories of misconceptions on atomic bonding, crystal structures, deformation, polymers, and electrical properties.

Support for Student Learning Survey

At the end of the course, students were given a survey asking them rate various aspects of the course based on how supportive they thought they were for student learning. Answers were in the form of Likert Scale where 1=Not Supportive at All, 3=Neutral, and 5=Very Supportive. Students were asked to rate various instructional strategies, hands on activities, concept contextualization, and an overall course rating. Additionally, students were given two statements in which they could strongly disagree (1), remain neutral (3), or strongly agree (5): "I would like to see some instructional strategies from MSE 250 used in other engineering courses" and "I would recommend to a friend to take this course".

Class Reflection Points

At the conclusion of every class, students were asked to fill out a Class Reflection. Each Class Reflection had three points for students to reflect on. The ***Point of Interest*** allowed students to think about and convey parts of content that they find interesting and intriguing. They began to recognize topics that interested them which promoted future appreciation of knowledge. The instructor identified with the learner and see what information sparked interests in the students' thoughts. The response to the ***Muddiest Point*** forced students to identify content topics which they had trouble understanding. By asking students to reflect on their difficulties in understanding, they learned to identify conceptual weaknesses. Frequent thought of these weaknesses enabled students to be proactive in their learning in the future. The instructor was able to catch conceptual gaps as they occurred and reduced the probability for students to develop robust misconceptions. The ***Take Away Point*** asked students to identify the content, skill, or piece of knowledge or learning found to be most valuable from the class. This allowed them to see relevance of content in their daily lives and build stronger connections between content and real world applications. The instructor began to see what students want to do with knowledge from the course. This gave the instructor insight as to how best frame content, which had implications of higher student motivation and self efficacy. Near the middle of the semester, a fourth point was added. The ***Learn about Learning Point*** asked students to identify what was learned about their own learning. This question enforced metacognitive thought processes in students which gave an opportunity to develop successful strategies for how to learn. Each class reflection was cataloged for each student throughout the semester. This resulted in a semester long progression of each student's thinking about each of the reflection points. From the 38 student sample of reflections, six students that were found to be representative of the class population were chosen and studied for trends in conceptual and metacognitive development. Their responses were coded through emergent themes coding. And their progress was followed

through their Class Reflection Points, Topical Module Assessments, and Support for Student Learning Survey.

Results and Discussion

Individual Student Semester Long Pathway

The students chosen for this study were discriminated against four different sets of data including consistency of entering a daily reflection point worksheet and their articulation, pre-assessment scores compared to post-assessment scores, the support for student learning study, and the engineering vernacular gains. Consistent daily reflection points were essential for selecting the students as it allowed for analysis of the student's introspections and helped us assess their learning, attitudes, and self-efficacy.

Student 1

The first student analyzed was representative of an average student based on pre/post tests, and they were representative of a student that did not like the class according to the category "Overall Rating of MSE Strategies to Support Learning" in the class evaluations. This student also gave the lowest rating in evaluations in the category "would you recommend this class to a friend?" The student showed very little general improvement in post-topic assessments over pre-assessments. The lack of improvement in assessments and dissatisfaction with the MSE learning strategies is reflected in the student's daily reflection points. The student had trouble paying attention which was supported by statements like "I tend to get distracted easily...","I doodle when my mind wanders...", "I need to not doze off in class...", and "I spaced out..." The student may have had the most trouble paying attention during lectures as their rating in the class evaluations for "mini-lectures" was the lowest rating possible. In one post-assessment the student scored lower than they did in the pre-assessment, and they showed no improvement in engineering vernacular in that topic. A daily reflection point for the lecture corresponding to the topic with the degraded post-assessment score was "In this huge section what are we expected to know/memorize for the test?" The student may have been having a hard time organizing the ideas to make them meaningful and memorable, and this is supported by the statements "How the heck are we supposed to memorize all of these fractures, concepts, and equations?", and "...You SERIOUSLY need to type up an algorithm for us to follow..." In another topic the student received a score close to zero on the post assessment, and in the corresponding topic on the class evaluations the student gave the lowest rating. The low ratings referred to in the support for student learning study for this student were not typical of their other ratings as the student gave normal ratings for the other topics, activities, and strategies to support learning.

Student 2

Student 2 was chosen to represent students with a positive attitude based on their daily reflection points. The quote from their daily reflection points that supports their positive attitude says "'I didn't fail the test, I just found 100 ways to do it wrong' - Ben Franklin..." Student number two also gave some very high ratings for class evaluations. They gave the highest rating possible for "Overall Rating of MSE Strategies to Support Learning" and for "Hands On Activities." They

also gave the second highest evaluation rating in the class for "Instructional Strategies Application." The student appears to have enjoyed the material as supported by the statements "If it's fun, it's easy [and vice versa a lot of the time]" and "Success!" On two post-topic assessments the student showed good improvement over pre-assessment scores, and this may support the notion that a positive attitude and good self-efficacy support learning. The student had a positive attitude throughout the class despite having some difficulty with the material based on the statement "I need to study" showing up a number of times in their daily class reflections over the semester.

Student 3

Student three was representative of a student with a negative attitude based on statements in the daily reflection points. When discussing the class grading curve the student said "...I just hope my classmates are really stupid." Their negative attitude toward the material in general is supported by their statement "Math sucks. Geometry sucks." Their negative attitude toward the professor was reflected by the statements "Holy crap - we finished a lecture!" and "I think your openings shouldn't take up 3/4 of the class." Student three had very little improvement on post-assessments compared to pre-assessments, and degraded in one post-assessment compared to the pre-assessment. The student's difficulty with the material is reflected in the statement "OMFG - I'm screwed for the exam." For the topic where there was degradation on the post-assessment the student stated in the corresponding topic reflection points "I had trouble drawing info from the graph...", "I didn't understand the graphs", and "I'm really struggling with the different defects." Some of student three's difficulty in learning could be due to a difficulty paying attention as indicated by their reference to having the tendency to talk in class in their daily reflection point "group activities keep me from talking in class." Despite having a negative attitude the student did not give all negative ratings in the support for student learning study. The student generally gave normal responses to most items, but gave the second lowest rating in the class for "Instructional Strategies Application" and gave the third lowest rating in the class for "Hands on Activities." They rated neither agree nor disagree for "Would you recommend this course?"

Student 4

The fourth student was representative of an above average student based on post-assessment scores, and they were representative of a student with a positive attitude change toward MSE strategies to support learning. The student had the highest possible score on one post assessment, and the third highest score in another post assessment, however their score degraded on one post-assessment. The "muddiest point" in the daily reflection points for the corresponding topic their post assessment score degraded on was "Various names & structures are hard to remember." While the student was above average, they were not at the top of the class, and this is reflected in the statement "...people work on homework and struggle to understand as they ignore the teaching teacher." Student four was also considered conscientious based on a high number of articulate responses in daily class reflection points. They did not miss any classes, and did not leave a single daily reflection point blank. Student four's initial reaction to the new MSE strategies to support learning is shown in the point of interest reflection point "Interaction in lecture; lack of 'learning' feeling (classic lecture sense) - may be learning in a new way, not sure yet." By the end of the semester the student appears to have had a favorable

reaction to the new MSE strategies to support learning. The transformation in their attitude toward the new MSE strategies to support learning is reflected in their daily reflection point for the last day of class "Having student and professor care about the learning improves the process & result." Student 4 gave the highest support for student learning study rating for "Context for Concepts." They also gave a good rating for "Overall rating of MSE strategies to support learning" and "Would you recommend this course." There seems to be a relation between conscientiousness, positive attitude, and learning as this student was above average in all three.

Student 5

The fifth student was representative of a below average student based on post-assessment scores. There was very little improvement over pre-assessment scores. Their difficulty with the material was reflected in many of their daily class reflections like "The homework was worded in a way that it was difficult to understand" and "I need my test scores to improve drastically." The student also had a number of "I'm confused" responses in daily reflection points. There was one topic where their score degraded, and twice in the corresponding topic daily reflection points for muddiest point they said "I didn't understand recrystallization." Another daily reflection point they had for a topic they had a degraded score in post-assessment was "I just don't understand what's supposed to be happening at the atomic level when materials deform." This student was below average, but they were motivated as evidenced by the statements in daily reflection point s: "study, study, study for the test" and "I need to spend more time outside of class working on this." The student was below average, but the student did not put the responsibility for their difficulty with the material on the professor as evidenced by the support for student learning study ratings. They gave a medium score on the rating for "Instructional Strategies Application" and they gave an above average rating for "Overall Rating of MSE Strategies."

Student 6

The sixth student was representative of a student with a high level of improvement based on post-assessments compared to pre-assessments. On the topic where they degraded on their post-assessment they said "I'm confused" a couple times in their daily reflection points. For one topic where they had a high level of improvement their "muddiest points" in the daily reflection points were "nothing today" and "nothing really." A couple of the student's post assessment scores were in the top of the class. They tied for the 3rd highest score in two post-assessments. The student appreciated the group work in the class as evidenced by the statements "I learned that I understand better when someone at my table reiterates the statements in 'dumbed-down' language." and "The people I sit next to help me learn." This positive attitude toward group work was also reflected in the "Support for Student Learning Study." Student 6 gave the highest rating possible for "team based discussions" but gave a low rating for "team presentations." The student gave a good rating of the "Overall Rating of MSE Strategies to support learning" but they gave the highest rating possible for "Would you recommend this course?"

Student Retention

To assess changes in student retention as a result of using Classroom Reflection Points, student retention from previous terms were compared. All courses examined were taught by the same

instructor. Student retention over each of the terms can be seen in Table 1. As shown, student retention was greatest for classes incorporating Classroom Reflections.

Table 1
Percentage of Student Retention per Term

Term	Retention
Spring 1996	10%
Spring 2000	18%
Spring 2001	11%
Spring 2002	11%
Spring 2003	14%
Spring 2007	18%
Spring 2009	5%*
Fall 2009	5%*

*Modules incorporating Classroom Reflections

Summary and Conclusions

Student responses to Classroom Reflection Points were linked to the gains exhibited on the Topical Module Assessments. Students with lower gains often showed signs of confusion through responses to the Muddiest Point. Students that had higher gains commonly claimed that there were no confusions in the class for the day. Points of interest varied from student to student. This was not often related to their conceptual development or how supportive for learning students ranked the course. Responses to the Take Away Point varied greatly across students. Some ranged from conceptual to metacognitive reflections. Often students claimed the need to study more often or specifically. Often these Take Away Point responses predicted specific ratings on the Support for Student Learning Survey. For example, students that claimed to have trouble paying attention in class often assigned a low score to the rating for mini-lectures on the Support for Student Learning Survey. Likewise, students who identified multiple Muddiest Points for a given topical area often rated that content area low on the Support for Student Learning Survey. These Classroom Reflections engaged students and gave them an active voice in class. This resulted in high retention rates compared to previous terms.

The use of classroom reflections supported student learning, attitude, and retention. Students exhibited conceptual gain throughout the semester. By taking time to reflect about knowledge that is being learned, students have the ability to relate new information to prior knowledge. This enables students to construct a coherent conceptual framework. Where lack of reflection might allow for incorrect conceptual connections, reflections such those to the Muddiest Point allow both students and instructors to become aware of and avoid potential misconceptions. Reflections to the Point of Interest give students the ability to express what topics they enjoy to the professor. From these reflections, instructors can utilize contextualization of examples that interest and engage students. These increased levels of engagement allow students to feel more connected to the class, increasing student attitude and retention. Responses to the Take Away Point allow students to identify the value in either concepts or in their learning. If students find information valuable, they may find it easier to assimilate knowledge. By reviewing student's responses to the Take Away Point, instructors can identify with students and frame content such

that motivation is increased. Increased motivation will positively affect self-efficacy and attitude, which, in turn, will increase retention.

By gathering frequent formative feedback through assessments such as the Classroom Reflection Points, an effective learning environment is created. Students learn. Students have raised self-efficacy. And students are retained. Retention has been a challenge of engineering in the past. Classroom Reflections are a simple tool that can offset that trend.

Acknowledgement
The authors acknowledge the support of this work from NSF IEECI Grant #0836041.

Bibliography

[1] Pintrich, P. R., & Schunk, D. H. (2002). *Motivation in education: Theory, research, and applications*. (2nd edition). Upper Saddle River, NJ: Merrill, Prentice Hall.

[2] Pajares, F. (1996). Self-efficacy beliefs in achievement settings. Review of Educational Research, 66, 543-578.

[3] Malka, A., & Covington, M. V. (2005). Perceiving school performance as instrumental to future goal attainment: Effects on graded performance. *Contemporary Educational Psychology, 30*, 60-80.

[4] Wigfield, A. (1994). The role of children's achievement values in the self-regulation of their learning outcomes. In D. H. Schunk & B. J. Zimmerman (Eds.), *Self-regulation of learning and performance: Issues and educational applications* (pp. 101-124). Mahwah, NJ: Erlbaum

[5] Miller, R.B., DeBacker, T., & Greene, B.(1999). Perceived instrumentality and the incentive value of academic tasks. *Journal of Instructional Psychology, 26*, 250-260.

[6] Simons, J., Dewitte, S., & Lens, W. (2000). Wanting to have versus wanting to be: the influence of instrumentality on goal orientation. *British Journal of Psychology, 91,* 335-351.

[7] Bandura, A. (1977). *Social Learning Theory*. Englewood Cliffs, NJ: Prentice-Hall.

[8] Yasar, S. (2008). Discourse in Freshman Engineering Teams: The Relationship Between Verbal Persuasions, Self-Efficacy, and Achievement. (Unpublished doctoral dissertation). Arizona State University, Tempe.

[9] Bandura, A.1982.The psychology of chance encounters and life paths. *American Psychologist*37:747–55.

[10] Yinger, R. & Clark, M. (1981). *Reflective journal writing: Theory and practice*. (Occasional Paper No. 50). East Lansing, M: Michigan State University. Institute for Research on Teaching.

[11] May, D. & Etkina, E. (2002). College physics students' epistemological self-reflection and its relationship to conceptual learning, *American Journal of Physics, 70*(12), 1249-1258.

[12] Surbek, E., Eunhye, P., & Moyer, J. (1991). Assessing reflective responses in journals. *Education Leadership*, March, 25-27.

[13] Smith, D. & Hatton, N. (1993). *Reflection in Teacher Education: a Study in Progress. Education Research and Perspectives*, The University of Western Australia, 20(1), 13-23

Appendix: Student Class Reflection Points

Student 1

Date	Point of Interest	Muddiest Point	Take Away Point	Learning Point
8/27/09	Learning about the different kinds of processes	Trying to figure out which bonding a material has predominately.	I guess I'll remember that ionic bonds are stronger than covalent.	
9/1/09	Learning about the different concepts each variable represents	The graphs are confusing	How bonding affects a materials properties	
9/3/09	I found that using pythagorean theorem applying to chemistry as opposed to math	I still don't know how to calculate BCC	How much engineers work together to solve problems	
9/8/09	Learning exactly what caused the Titanic to sink. Molecular structure	Nothing really, I just can't "comprehend" the zinc-blend structure	How much the BCC, HCP, FCC contribute to a structure's properties	
9/17/09	learning about specific properties of materials (stiffness, elasticity, etc.)	How to calculate the information from a graph	To look at the ENTIRE problem and solve all questions	
9/22/09	Ripple in the rug	absorbing all the information	That I really need to learn faster	
9/24/09	Well, it's all just review. I guess its dealing with density, number of atoms, etc.	I have no idea how to get the =#Unit cells/cm^3	Remembering the kinds of bonds between materials	
10/4/09	different kinds of failures	how to pinpoint exactly which situation results in what kind of failure. Info is all over the place	learn how to solve problems (defects)	
10/6/09	pinpointing which fault causes failure on both micro and macro scales	how the heck are we supposed to memorize all of these fractures, concepts, and equations	that different types of failures affect different objects in different ways	
10/15/09	the different ways that process can change properties	I still don't know what annealing is	metals deform similarly	I get distracted easily. I saw the saxophone and my mind wandered to music
10/20/09	I thought the whole concepts of liquid vs. solidus was pretty cool. Anything above the liquidus line is liquid, and opposite for solidus	I'm getting lost with L+α, or even what α or B are	the eutectic region concept	well, I kept "correcting" myself even thought I was right the first time
10/29/09	Steel microstructures drawing	Definitely the drawings of the microstructures	I need to memorize defects	I need to not doze off in class and take notes
11/5/09	phase transformation of the metal due to temperature. Pearlite - bainite: finer grain; stronger it is	actually it actually does make sense	finer grains and lower temp strengthens the metal	At the beginning I was finishing up last time's HW and I kinda wasn't paying attention
11/10/09	the thing where you stretch the rubber band and it gets warm in front of your mouth.	just memorizing everything (all kinds of plastics)	the recycling numbers	I learn best in active learning environments
11/19/09	Of course it's the fact that we make faster computers for intense gaming	what exactly is an integrated circuit	Difference between n- and p-type semiconductors	I spaced out when we came to the LEDs, and I kept asking irrelevant questions to myself.

Student 2

Date	Point of Interest	Muddiest Point	Take Away Point	Learning Point
9/3/09	Learning how to find the face diagonals and body diagonals of the different cubics.	The formulas for the cubes (FD and BD)	Success!	
9/8/09	The disasters because of error in crystalline structure development	Isotropic and “the other” – tropic and what they have for effects in metals/crystalline structures	The crystalline structures are very important in determining properties of metals or other materials.	
9/15/09	Finding planes given indices and vice versa	Area of the different planes. (planar density of atoms)	Need to figure out how to find area of planes	
9/17/09	Discovering the graphing techniques and he important points on the graph f strain vs. stress	How can something have the highest strength and be the most brittle	I learned how to distinguish what kind of material is being represented on a graph	
9/24/09	How terrible I feel about the test Tues.	The review	I NEED TO STUDY	
10/4/09	"I didn't fail the test, I just found 100 ways to do it wrong" - Ben Franklin I should try this sometime.	why did the titanic sink?	listen to engineers; they save lives	
10/8/09	How certain metals can be diffused	the mechanisms of diffusion	I've learned how certain aspects of a metal or alloy affect the type of diffusion that occurs, and at what activation energy.	
10/13/09	The combination of annealing and cold working	recrystallization	Test Oct. 29th	I'm better with an understanding of the subject /process instead of equations alone
10/15/09	cold working	hot working/recrystallization (that softens the metal)	working with metal with hotness and coldness is interesting	I'm a hands-on learner
10/20/09	phase diagram interpretation	different graphs of % sugar in solution	I know the effects of composition on the eutectic reaction	I don't like symbols
10/22/09	The eutectoid, as a word.	The compositions at different phases (single or two)	Time to review	I learn when I pay attention
10/29/09	Phase diagrams	microstructures	Need to study A LOT!	I learn better with hands on activities
11/5/09	the strength differences of alloys after time	phase transformations	I learned more about the purpose of microstructures and how to draw them	I need visual information along with verbal to be the most effective learner
11/10/09	The direction of the chains of a plastic bag can be found by stretching the bag in N/S and E/W directions	polymer crystallinity	hopefully homework grades can be dropped	hands on is fun and interactive
11/12/09	The strengths of some polymers	How to know what type a certain polymer is classified as	I learned today about the last class's discussion which is good	If it's fun, it's easy [and vice versa a lot of the time].
11/17/09	the effects of temperature and impurities on conductivity	extrinsic and intrinsic semiconductors	this was an interesting lecture and we should have done a hands on experiment with it	I learn best when I get a good night's sleep

Student 3

Date	Point of Interest	Muddiest Point	Take Away Point	Learning Point
9/1/09	resistance & conductivity	All of the graphs, I feel like you spend so much time ranking conductivity etc. That you didn't explain the graphs. Also, I wanted to know about superconductors and wish you didn't dismiss that question	I'm really confused by the graphs	
9/8/09	I thought it was interesting how the sequence of atoms determines the shape. I also liked that you went over the applications.	I liked that we went over the applications, and I understood a little of why, but I was focused on the depictions.	Me thinks your openings shouldn't take up ¾ of the class	
9/15/09	figuring out the planes was challenges/interesting	What does this mean? How can something break along a plane? Wouldn't that mean the atoms would have to split?		
9/17/09	how all these properties relate	I had trouble drawing info from the graph, but perhaps that's just because I didn't have time to really process the information. So does the MF at the top mean male or female? And if it does, is I referring to sex or gender?	This is probably one of the key parts of this class because this is what you would look at to help find an ideal material.	
10/1/09	I thought the Aloha Airline falling to pieces was cool. Anything that's related to doom is immediately interesting to me. And the micro pictures of the breaks were cool.	why temperature affects the material that relates back to the unit cells right?	knowing of how materials fail	
10/8/09	the equations and graphs	the different types of diffusion	how atoms diffuse	
10/13/09	The processing methods	The equations	Dislocations	Turns out is I'm not using my hands, I can't pay attention.
10/15/09	strength & recrystalization	difference in dislocations & defects? I'm so confused!		group activities keep me from talking in class
10/22/09	phases of steel	EVERYTHING		I really like bulleted notes that I can apply to a graph, rather than understanding it all at once.
11/12/09	How the graphs work			I think it's easier to have charts memorize them, then put all the info together and understand it.
12/8/09	the test 3 material overview of polymers, semiconductors and metals. Mostly semiconductors	Ferrous alloys, grain growth etc. Processing of metals & their effects	an understanding & overview of what material engineers do & the conventions they use to study	I learn better when I like the people I'm around

Student 4

Date	Point of Interest	Muddiest Point	Take Away Point	Learning Point
9/1/09	Relation of properties & whether they are really related & how it affects models	bond gap	Attention: had issues today - having to relearn how to pay attention (in usual class can zone/filter out a lot -haven't gotten that yet & get lost in too much info) - still took in info, just might have missed stuff	
9/10/09	angles between directions	Linear Density (why & how)	be careful with #'s	
9/15/09	visualization of structures	[] is () for vectors & planes	visualization	
9/22/09	how ripples continue after impediments	unclear alloy names: want to know about strength of materials and defects	defects can be good or bad depends on goal	
10/13/09	how a metal could be worked and manipulated	The rarely covered formulas (what they describe, derivation, assumptions)	dislocation are what determine metal strengthen	Today: I think too much based on what I think the audience is expecting. Since the beginning: I've learned that I filter much of the information (in other classes, I did this without noticing). I had to re-learn how to do I for this class. (By filter I mean what information isn't important and can be forgotten without consequence)
10/15/09	the picture was wrong - grain boundaries are biggest won Δ absorb smaller	was I right about sugar activity? (answers)	better knowledge of strength based on hot & cold working	What a person is capable of in a class is heavily based on previous experience…
10/20/09	alloy composition phase diagram	some definitions were unclear/guessed at. The reference page is helpful	Equilibrium is unaffected by supersaturation	I pay more attention to a new person but am far more doubtful of a substitutes teachings/facts/anything they say
10/22/09	how much can be found using graphs	lots of names, slow to remember	pictures in the book are easier to see	learning from a person is easier than a book for me because I have a better attention span for people than text.
11/5/09	sitting at room temp can increase strength	#15 HW - finding YS & %El; how to draw martensite	FCC = σ, BCC = α, BCT = martensite	I make adjustments as time goes on. (I adjusted to test format & studied better)
11/12/09	Ability to predict properties based on repeating structure	Thermosetting	Material properties based on log(E) vs. Temp graphs	Being called on to answer questions I don't know the answer to can teach me
11/17/09	how temperature affects sigma and roe	there are band gaps between every molecule and atom, right?	how LEDS work	For me, it's easier to pay attention the first time than it is the 100th time
11/19/09	Why polymers are worse conductors than ceramics	What determines bias in rectifying junctions? Where are the band gaps?	Wafers got bigger	Being dependent on a table then having it taken away makes me seem far less intelligent (polymers and pot-assessment)
12/8/09	Practical application of microstructures	Polymers-naming primarily	practical application of microstructures	Having student and professor care about the learning improves the process & result

Student 5

Date	Point of Interest	Muddiest Point	Take Away Point	Learning Point
9/1/09	The higher the melting point, the lower the thermal expansion. Its kind of obvious if you just think about metals vs. plastics	The HW was worded in a way that it was difficult to understand	Bond energy is very important for conductivity	
9/3/09	The geometry of cubics was very interesting to me. It's something I can visualize quite easily	I took quite a while to figure out how to solve for the body - centered cubic because we didn't realize substitution was the key	You can use substitution to figure out how to solve these problems if you have two unknowns	
9/17/09	The smaller an indent a material makes, the harder it actually is.	I just don't understand what's supposed to be happening at the atomic level when materials deform	I need to learn what these different measurements of strength actually represent	
10/1/09	Failure can occur because of variables that engineers don't always take into account in prior testing.	I clearly have to be better prepared for the test	make sure to understand every concept learned in here	
10/8/09	diffusion in metals allows carbon to diffuse into iron or steel alloys that can then be heat treated to harden where knives can be increased in strength by IOX.	I don't know how to tell what the mechanism is just by hearing "Cu in Zn" or "C in Fe."	Diffusion can be analogous to a person fitting through "fat man's pass" A larger person is similar to a vacancy diffusion, because it requires more energy than an interstitial atom.	
10/13/09	Smaller grain sizes create greater overall strength because there are more "rooms" in which form barriers	I didn't understand the recrysallization temperature problem	Temperature is very important when it comes to shape and property control	When we went over problem 1 from Hw #10, I helped me to better understand how I was supposed to solve this problem. I learned that I learn best with example problems
10/20/09	I thought that phase diagrams were interesting	I still don't know how to graph the solubility plots	I need to study more	I learn better by being interactive
10/22/09	the tallest building in the world at the turn of the century was only less than 200 ft. tall	I think phase diagrams are still difficult and are important to know for the test	I should study more	I learn best when I'm genuinely interested in the material
10/29/09	Phase diagrams	What's on the test?	Study a lot	I learn best during interactive activities
11/5/09	you can overboil water in the microwave	Isn't it a bit precarious that there are bell curves?	I need my test scores to improve drastically	I learn best when I'm focused
11/10/09	I felt that the YouTube video of nylon was fun	I think that determining the type of polymers is difficult for me	this is something that makes more sense to me	I learn best when I'm not tired
11/12/09	The bullet penetrating the vest	Polymer crystallinity	I will ace my next test, unless the class performs very well	I learn best when I like what I'm learning
11/19/09	Mint lifesavers spark in the dark	Intrinsic semiconductors	Study for test after Thanksgiving	I learn best when I pay attention the whole time
12/8/09	I felt that the most interesting part of this course was unit cells	the most confusing part was stress strain diagrams	I should learn more about materials before enrolling in a future course such as this one	I learn best when I'm with people who know the material about just as well as I do

Student 6

Date	Point of Interest	Muddiest Point	Take Away Point	Learning Point
8/25/09	Team activity	glass bond=covalent. What exactly a metallic bond is?	what a glass and metallic bond is	
9/1/09	The relationship between p and k	example 3 on HW #1	Young's Modulus + Hooke's law.	
9/8/09	The 1st activity, the table with the Titanic rivets, the tin button, and Grandma's hip replacement, It helped me visualize.	Probably density computation	Tin buttons in cold weather are a bad idea	
9/10/09	How steel weakens w/heat + that swords use low + high carbon steel + FCC is more dense, but is more soluble due to structure	Drawing the vectors	Realizing we were doing vectors	
9/15/09	discovering 1/0 = infinity or infinity → 0	area of planes	Difference between direction vectors + planar vectors	
9/22/09	The caterpillar method	the rug method	defects actually make things better	
9/24/09	Spark plugs are ceramic	calculation of density	vectors and plane directions	
10/1/09	Hawaiian airline stewardess getting sucked out of the plane	the difference between micro and macro causes.	cold destroys ductility	
10/6/09	that most failures occur to lack of maintenance or inspection	the difference between macro and micro fractures	stress-corrosion is a combination failure	
10/8/09	the diffusion process of ceramics	How to use the equations to find diffusion	how activation energy is temperature independent	
10/13/09	The new way to look at dislocations	when determining diffusivity why two things (x+C) are considered constants?	What strength of a material actually means	I learned that I understand better when someone at my table reiterates the statements in "dumbed-down" language
10/15/09	how dislocation density matters more than grain size	nothing today	same as "point of interest"	I learn better w/background noise
10/20/09	so confused	everything	Please don't leave Professor Krause	I don't learn well when people assume I know what I don't
10/22/09	how before steel structures used no tension	nothing today	the eutectic diagram is extremely useful	I like the matching
10/27/09	no comment	steel microstructures	Microstructures w/ just alpha + beta	I get confused easily
10/29/09	Conductivity of alloys	microstructures	Nil-ductility is an important test	I don't learn will when rushed
11/5/09	cooling rapidly makes steel stronger	better microstructure understanding	The guy I sit next to is mildly-retarded	the people I sit next to help me learn
11/10/09	how the rubber band got cold	nothing today	polymers shrink when heated	the objects in front of me helped
11/12/09	How zylon® failed.	Probably the 4 regions of polymers	Kevlar rocks	N/C
11/17/09	silicon is awesome	nothing today	LEDs are awesome too	I like the visuals
12/8/09	How thing keep getting small but faster	nothing really	Inflation is insane	I like it how that I can relate to things how (i.e. games/comps.)