Cyber Learning Applications in Core Materials Courses

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Abstract

Engagement, assessment, and reflection tools in an interactive cyber-enabled web environment are currently being studies by a TUES Type 2 project. The launch of three new NSF-supported, web learning and assessment platforms; the *Concept Warehouse* http://cw.edudiv.org, the *Concept Inventory Hub* (ciHub) (http://dev.cihub.org/) and a public site, *Materials Concepts* www.youtube.com/user/MaterialsConcepts are utilized. Using the tools in and out of class has should improve the effectiveness and efficiency of learning using frequent formative feedback to students. Compared to lecture-based pedagogy, constructivist pedagogy showed greater conceptual learning gains, improved student attitude, and increased class persistence. This document discusses issues of implementing classroom change using the JTF strategies at four diverse institutions and also reports on the impact of using student Muddiest Point, end-of-class reflective feedback on both instructors and students at the diverse institutions. Results indicate positive student reactions for approaches used that support their learning. Faculty also report positive changes in pedagogy to address student issues in efforts to achieve more effective learning.

Keywords: Cyber-learning, Material Science, pedagogy, constructivist

Introduction

A current project is creating and studying frequent formative feedback which has the potential to enhance both instructor teaching and student learning [1, 2]. The process enables more effective instruction with instructor Just-in-Time-Teaching tools and student learning with Just-in-Time-Learning resources. The instructor feedback helps students monitor their construction of knowledge and define the knowledge. Students can then strategize which resources to select, including those described in this paper, in order to reduce or ultimately close that knowledge gap. This metacognitive strategy contributes to self-regulation that leads to deeper conceptual learning and the achievement of learning goals. The ease-of-implementation, impact, and effectiveness of the JTF pedagogy for enhancing student performance are being tested in collaboration with faculty in diverse settings at four institutions of higher education. The team realizes that there is no "one size fits all" when it comes to instructional tools for classroom and out of class usage. This work is looking at, "The effect of formative feedback, engagement pedagogy, and use of web-enabled resources on student outcomes across diverse settings?"

Web-Enabled Instructor Tools and Resources

We live in a connected world. Our students navigate the web spaces at a frequency to be envied by older generations. Now the team is implementing improved teaching and learning tools in a web setting. In particular, two instructor Just-in-Time-Teaching tools were web-enabled on an automated assessment site Concept Warehouse (CW) at http://jimi.cbee.oregonstate.edu/concept_warehouse/. 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. Shown below in Fig. 1 is the set up for tab view for setting the response time window for collecting students' Interesting and Muddy Point questions. 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.   Also of interest is that the tool is free. The research team is now implementing the muddy point tool onto the Blackboard platform but as of yet Blackboard does not offer the features of the Concept Warehouse in that it does not have the ability to generate the word cloud.

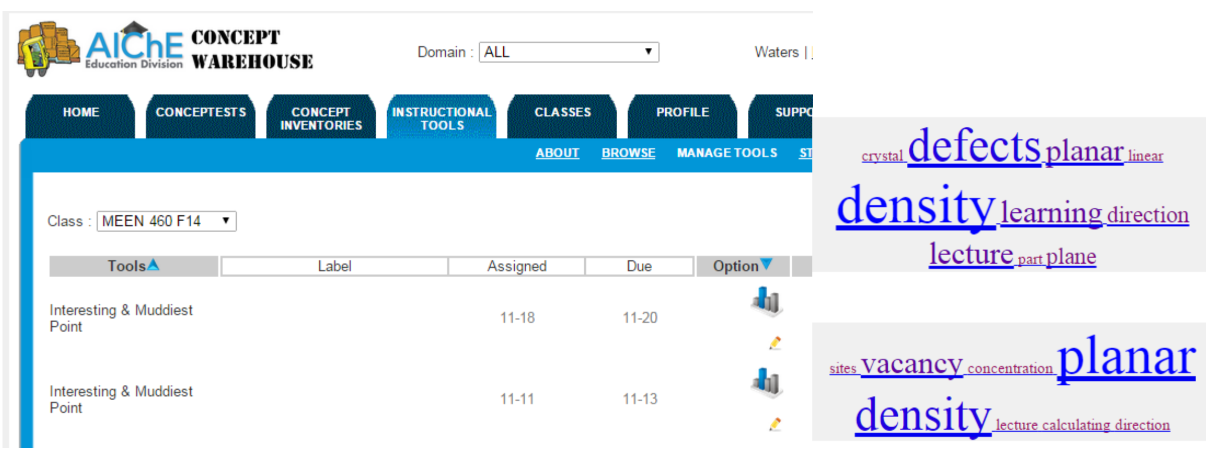

Figure 1. Concept Warehouse set up tab view for setting the response time window for collecting students' Interesting and Muddy Point questions and the generated word cloud.

A second resource contains slide sets for each Muddiest Point video, http://www.slideshare.net/mseasuslides/presentations. 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.

These complementary student Just-in-Time-Learning web resources close their knowledge gaps and achieve their learning goals in the process of actively constructing their own knowledge [5]. 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 [6].

III. Results and Discussion

A. Two-way Formative Feedback Reflections

A critical function of the second part of two-way formative feedback is the next-class instructor response to a previous set of student comments from the muddy points [8] as shown in Figure 1. Such reflections can promote metacognition in students' thinking and also instructor reflection on his/her classroom practice. Before 2013 these reflections were done by pencil and paper and collected at class end, after which data was transcribed into an Excel matrix and then summarized by an involved student for the instructor. This was tedious and as such served as a barrier to faculty implementation. Now, in using the *Concept Warehouse* web tool, there is an automated open response box function to record student thoughts, which greatly facilitates data collection and analysis.

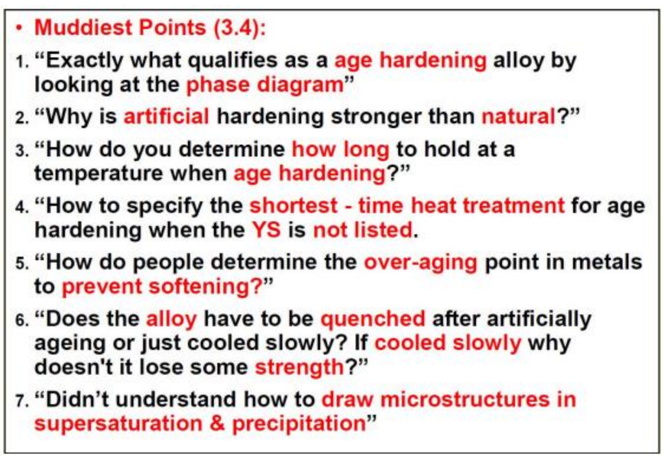

Figure 2. Summarized set of student Muddiest Point Reflections on the topic of age hardening of aluminum alloys.

A question posed is, “what happens after the student reflection data set on Most Interesting and Muddiest Points is collected”? In traditional, lecture-based classes feedback is only summative – that is, after an event, such a test. Likewise, homework grades are also, in a sense summative, because much of it is graded by points with respect to how correct or incorrect an answer is, which may not reveal underlying issues responsible for loss of points. Furthermore, for a given a topic, the lecture, readings, and homework are structured by an instructor. As such, information about student understanding is limited to the framework determined by the knowledge, understanding, and skill of the instructor without any possible input on the part of the student. It seems likely that an instructor could be more effective in his/her teaching if he/she knew what the nature was, of the students' background, prior skills and knowledge, strengths, weaknesses and misconceptions as related to a given topic. Two-way formative feedback addresses this issue.

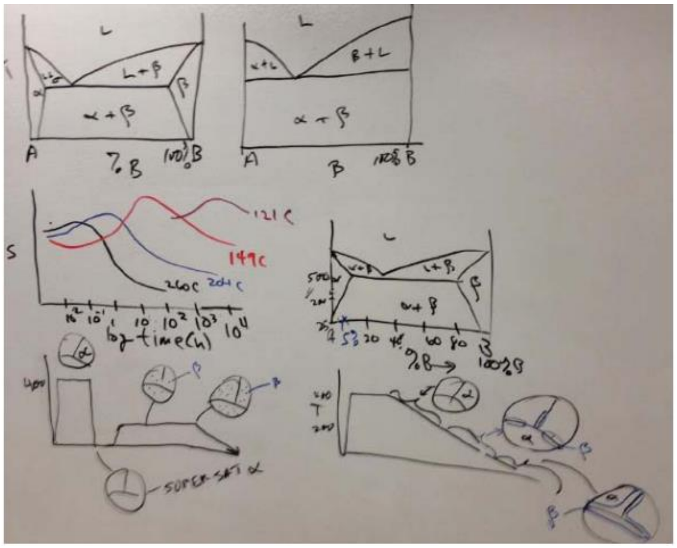

Figure 3. Faculty response on class white board to students' Muddiest Point Reflections on age hardening of Al alloys.

When students respond from their viewpoint about their thoughts (e.g. muddiest points) on content, concepts, problem solving strategies, and more, their answers will extend beyond the boundaries of the framework an instructor uses to organize and communicate, and then assess and evaluate knowledge and understanding of students. So, if there are hidden issues in student learning such as misconceptions, skill gaps (like charting), difficult concepts, vocabulary ambiguities, etc., the instructor may never become aware of them or their existence. And, such issues may continue to persist, sometimes beyond a course, with a resultant negative impact, not only on student performance, but also on attitude by loss of self-efficacy and, even reduced persistence because of lesser grades and/or poor attitude. One approach to this issue is embedding formative feedback into instruction so students can communicate their learning issues to the instructor, as the first part of the two-way formative feedback, which instructors can then respond to by targeting specifically the issues with which students have been struggling, the second part of two-way feedback. In formative feedback students' needs and issues are the defining framework of learning issues, impediments, or barriers that the instructor needs to address for more effective teaching and learning. In effect, students are empowered to play a role in their learning when they provide input about their instruction.

Formative feedback research and theory has been extensive and sometimes controversial, but meta-analysis papers reveal some interesting conclusions on impact related to timing of formative feedback and the type of student receiving it [1, 2]. When a given part of class content on a specific topic is simpler, immediate formative feedback is most effective, especially for the type of student with more limited capabilities. On the other hand, if a given part of class has more complex or difficult content, then delayed formative feedback is more effective and is more useful for the more capable type of student. In a class engagement activity, questions or comments to students or teams by an instructor or teaching assistant would be considered immediate feedback. On the other hand, delayed formative feedback might be given to students later, for example, in an instructor's office, or the next class (possibly with Muddiest Point feedback), or by a graduate assistant in a recitation section or exam review.

With respect to the link between the student Muddiest Points in Figure 1 and the instructor response in Figure 3, there are actually two primary underlying issues, which are being addressed. It would also be unlikely for them to be addressed by an average instructor because he/she would likely make assumptions about the strength of particular student vocabulary and skills required to understand the concepts and associated significance. The first five Muddy Points relate mainly to students' lack of ability to read and interpret graphs. There also are possible associated vocabulary issues. The first comment relates to the definition and meaning of the term "supersaturated" and how to interpret it from the first two phase diagram graphs – which can possibly give a supersaturated alloy The one on the left does have a solubility limit line decreasing with temperature at both ends of the phase diagram, and supersaturation is possible. However, in the right graph there is no solid region where one element could be soluble in the other in the solid state. With no solid solubility, a supersaturated solid solution cannot be created. So the underlying reason(s) for difficulty in understanding the first explanation could lie in poor chart reading ability, vocabulary, or in the meaning of solubility limit or all. The response addresses all issues with the two graphs, but could have been improved with better labeling on the diagrams.

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

Finally, the last two items have similar student learning issues related to translating graphical information to the underlying microstructure. These were addressed in the response, which made strong use of graphs and images to address misunderstandings about links between a material's microstructure and the resultant macroscopic properties. Once again, if such a problem would be encountered with traditional teaching on a homework problem or an exam, it is likely that, if a particular problem was marked wrong, it would not be explained. Formative feedback responses address this issue. 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. In the example here, the axes, graphical curves and associated microstructures were explicitly connected to hardness. Overall, visual and graphical images connected to plots and labeling key elements of images and plots helped make content more accessible to students.

Thus, reflections can pose an interesting challenge to the instructor who may take the opportunity to help students reduce or close their knowledge gaps with this delayed formative feedback. This builds on prior knowledge of the content developed in reading text, looking at notes and slide sets, and solving homework problems. Later, student study strategy results discuss how students use their resources to spend the shortest time possible while achieving the largest knowledge gain by most efficiently using resources available.

B. Student Resource Value Survey (SRVS)

We design tools for students but in order to examine 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, as shown in Figure 4a and, and to resolve confusing concepts in Figure 4b. This tool is referred to as the Student Resource Value Survey. The tables below show the categories that are covered for a single instructor's course. There are core resources that are applicable to all instructors but there are also custom resources used by a given instructor which are aligned with his/her own classroom practice and specific resources.

1. How often did you use the following resources to help you study for your exam?	**Exam 1**	**Exam 2**	**Exam 3**
a) your own classroom notes	86%	92%	87%
b) homework problems	81%	74%	61%
c) posted lecture slides	72%	74%	92%
d) old exams or quizzes	78%	79%	95%
e) textbook readings	28%	16%	21%
f) classmates/friends	56%	58%	61%
g) instructor	25%	24%	39%
h) teaching assistant	25%	45%	76%
i) tutoring service	25%	8%	8%
j) exam review session	53%	79%	82%
k) in class muddiest point responses	28%	34%	32%
l) youtube muddiest point videos	47%	42%	68%
m) quizlet.com e-vocabulary flashcards	33%	32%	24%
n) slideshare.com slide sets	14%	8%	13%
o) google	61%	42%	47%
p) other	17%	3%	5%

Figure 4a. Student Resource Value Survey for Exams

3. Which of the following resources do you use when you encounter a confusing concept?	Exam 1	Exam 2	Exam 3
a) your own classroom notes	81%	89%	89%
b) homework problems	56%	58%	55%
c) posted lecture slides	72%	76%	82%
d) old exams or quizzes	42%	47%	63%
e) textbook readings	58%	39%	37%
f) classmates/friends	69%	61%	63%
g) instructor	25%	18%	39%
h) teaching assistant	44%	42%	71%
i) tutoring service	19%	3%	11%
j) exam review session	36%	53%	74%
k) in class muddiest point responses	44%	32%	39%
l) youtube muddiest point videos	53%	61%	66%
m) quizlet.com e-vocabulary flashcards	42%	21%	18%
n) slideshare.com slide sets	14%	13%	13%
o) google	81%	55%	58%
p) other	14%	5%	5%

Figure 4b. Student Resource Value Survey for Concepts

In order to become a more effective instructor, it was thought it would be useful to develop a survey, which assessed what strategies and resources students used to prepare for exams and to address confusing concepts. Figure 4a shows a set of responses over 3 exams, of 34 to 37 students in a materials class, to the general question of, "How often did you use the following resources to study for your exam?" There was a Likert scale rated 0-4 with 0 being never and 4 being always. The table shows per cent of students that responded to a resource use with value of 3 or 4. The survey was given in the class preceding each of three hourly exams. The same resource set was used in Figure 4b, except it was resource use for confusing concepts. 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 the author's own classroom. Some observations and trends will now be discussed.

With respect to exam resources used, a few questions asked 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 taking an engagement and web resource class? Data from Figure 4a showed the following. The most heavily used resource, from 86% to 92%, was a), the class notes, 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. Conversely, the publisher's textbook e) was among the least used resource at 16% to 28%. So it seems that students substituted the modified engagement class slide set notes for reading the book, at least for exams. Web based resources received moderate use. The Muddiest Point YouTube videos, l) increased in use from exam 1 to 3 from 47% to 68% and the e-vocabulary site, m) received decreasing use, from 33% to 24%. Google o) use from exam 1 to 3 was moderately high, but decreased from 61% to 47%.

In terms of personal interactions and changing resources there was significantly increasing use of the teaching assistant h) from exam 1 to 3 from 25% to 45% to 76% and similar increases in exam reviews j) from 53% to 79% to 82%. Clearly, the teaching assistant has changed students' study strategies, which was also reflected in exam performance with well more than half of the class receiving A or B on all tests. This was also equal to or better than the same course taught by the same person, an author, for more than 12 courses over the past seven years. It might also be noted that, from exam 1 to 3 that, students use of classmate/friends, f) slightly increased from 56% to 61%, which shows considerable interactions between students when studying for exams, which is likely beneficial. The final note is that, from exam 1 to 3, use of instructor, g) as a resource, increased somewhat from 25% to 39%. This may correspond to providing more detail on Muddy Point responses during the time between exam 2 and 3. Trends in resource level usage for confusing concepts in Figure 4b were generally similar to values for the exams, except that textbook usage, e) was about double that of exam preparation, and did decrease from 58% to 37% from exam 1 to 3. This may show that students did value the text when first learning the material, but as the semester wore on, shifted their learning strategies more to e-resources and personal-interaction related resources, especially the teaching assistant. So, overall, web resources are used significantly to prepare for exams, more so than the textbook. A significant result is that resource over time is not static, but does change. The most striking change over time is the dramatic increase in use of the teaching assistant and associated exam reviews from exam 1 to 3.

C. Student Impact Value Survey (SIVS)

In order to assess impact of web and engagement pedagogy with Muddiest Point two-way formative feedback, a survey was created to assess the impact of JTF pedagogy on student attitude in terms of interest (motivation), utility, and cost. As such, a Student Impact Value Survey, shown in Figure 5, was developed and administered to assess impact of the JTF web and engagement pedagogy on students. Five classes at 4 institutions all had very positive results discussed here.

STUDENT VALUE OF MUDDIEST POINT REFLECTIONS: RESULTS
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%

Figure 5. Student Impact Value Survey results.

The survey was given to five classes at 4 institutions with all having similar levels of very positive results discussed here. For the five fall 2013 term classes student persistence was also measured. The results are analyzed with respect to three major factors: interest/attainment value; utility value, and cost. These results are discussed below.

1) Interest/Attainment Value: Interest or intrinsic value is 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. Positive results of 59% to 79% suggested that the majority of students found muddiest point reflection to positively impact their experience in the class.

2) Utility Value: Utility value is an individual's perception of the advantages that result from engaging in the task for future goals or rewards. Very positive results from 79% to 93% suggest that students overwhelming found the material learned in the course to be of value to them in their current and future endeavors as learners and professionals.

3) Cost: Cost represents an individual's perception of sacrifices required, including effort, time, and psychological impact, for successful impact of an activity. Results of 83% to 85% suggest students did not find muddiest point reflections to be a frustrating activity that took too much time and effort.

It can be seen from the results above that the use of muddiest point reflections is a simple intervention that is capable of having major impact on course outcomes. The benefits of such two-way formative feedback are the associated gains for both instructors and students. From a student perspective, the survey revealed overwhelmingly positive value toward the muddiest point reflections. Students saw this opportunity as a way to positively impact interest, attainment, and utility value without too much negatively associated cost. Such results suggest that students found muddiest point reflections improved the course in a way that made the course more enjoyable and valuable. This increase in value resulted in high appeal for the course by students. While this final result is likely impacted by the course content and the instructors themselves, the instructors can still appreciate the students' views using such two-way feedback activities as a means of having better insight on student learning issues.

SUMMARY AND CONCLUSIONS

Faculty are many times slow to innovate in the classroom and the new technologies for teaching and learning have been a barrier to innovative teaching strategies and materials. In an earlier NSF-sponsored project, the very same Just-in-Time-Teaching pedagogy used class-end pencil and paper Muddiest Point student responses as feedback to the instructor. The amount of effort in compiling and assessing data was cumbersome and was not been adopted in other engineering education settings. That issue has been solved with the Concept Warehouse. Now there is the potential for broader adoption and implementation of JTF web and engagement pedagogy with two-way feedback that not only promotes metacognition and improved achievement of students, but also promotes instructor self-reflection that enhances effectiveness and efficiency of teaching. As such, student assessment results gathered at different time intervals across the course allow the instructor to provide the *two-way* formative feedback needed to adjust instruction to address serious learning issues such as robust misconceptions and difficult concepts.

Thus, some less difficult student-learning issues can be addressed in class with immediate formative feedback, while more difficult issues can be addressed with delayed formative feedback in the next class and longer-delayed formative feedback prior to an exam. Cyber-enabled tools provide more flexible and efficient and effective resources for both instructors and students. Employing such strategies and cyber-enabled tools has simplified instruction and improved student attitude, learning, and persistence. This would have the potential to facilitate adaptation of as least some aspects of the JTF approach and promote diffusion of its innovations.

The impact of JTF has been positive, and has proven to be easy to implement which lowers faculty resistance to use. Additional support of the techniques is the fact that Wiley Publishing is modifying some of the resources to their e-learning platform, Wiley Plus. The e-learning student resource is linked to two widely-used materials textbooks authored by Callister and Reschweth, including the new 9th edition of their best-selling book, Materials Science and Engineering: An Introduction. An undergraduate introduced to concept of muddy points by her home faculty has been hired by Wiley publishing to create resources for the electronic part of their book website.

The ease-of-implementation of the types of strategies, tools, and resources could be developed and used in other engineering domains. Although the principal disciplinary field of the JTF project has been engineering education directed toward the subject of materials science and engineering, the vast majority of students are from mechanical, chemical, industrial, and a few other engineering disciplines. So the types of general approaches, tools, and assessments that were created could be used by all instructors if they wanted to use the tools and technologies for their own disciplinary use.

Acknowledgment

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Dr. Cindy Waters is an assistant professor in the Mechanical engineering department at NCA&T state University. Her BS and MS are in Materials science from Va. Tech and PhD in mechanical engineering. Research focus is on advanced materials both in the macro and nano range. Her lab, the Advanced Metallic Materials and Porous Structures Research Lab (AMMPS), research lab has a focus on basic research for developing new techniques to manufacture metallic porous structures with desired structure, and properties; and to understand the physical phenomena that controls this synthesis such as diffusion, nucleation, and phase transitions. Her aim is to create new materials along with improving the properties and performance of existing materials by altering their manufacturing techniques and by studying their micro-structural and mechanical characterization and their failure analysis. Dr. Waters is currently working in the areas of 1) porous metal, and 2) cellular materials, and 3) Engineering Education. She holds NSF funding for 5 different NSF Engineering education grants 2 of which she is the PI and 3 the Co-Pi. Her work involves materials science pedagogy and faculty resistance to implementation.

Dr. Steve Krause

Stephen Krause is Professor in the School of Materials in the Fulton School of Engineering. He teaches courses in general materials engineering, polymer science, characterization of materials, and materials selection and design. He conducts research in innovative education in engineering, including a Materials Concept Inventory, and also in adapting design, engineering and technology concepts to K-12 education. Understanding conceptual development in undergraduate chemistry and materials engineering and development of a chemistry concept inventory and a materials concept inventory is a focus for his research. He has co-developed a Materials Concepts Inventory and a Chemistry Concept Inventory with NSF funding from the Foundation Coalition. Other innovative tools include the Materials Mentor fold out notes, Materials Lecture Work Notes and Materials Lecture activities. Adapting engineering design principles for K-12 education through graduate education courses and development of a high school engineering signature program