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The iCollaborate MSE Project: Progress Update 2013

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Abstract

The iCollaborate Materials Science and Engineering (MSE) project is a comprehensive research program that has an overarching goal of improving student outcomes in introductory materials engineering courses. The project is multifaceted and includes several interwoven components, all of which are founded upon literature based best practices in STEM education. The project components include: a detailed study of pre-course knowledge and misperceptions, an investigation of student preparation influencing course outcomes, an analysis of Index of Learning Styles (ILS) data, a switch to inductive teaching practices which include collaborative, active learning modules and concept/peer learning opportunities, collaborative writing of research papers, low stakes quizzing, the development of targeted iPod applications that promote enhanced student understanding of known conceptual difficulties, MSE vocabulary terms, visual and conceptually contained presentations of material properties, material calculators and conversion tools, and the development of a web site based upon concept maps. The project includes formative and summative assessment elements.

This paper focuses on previously unreported components of the iCollaborate project that were researched, analyzed or developed during the 2011-2012 academic year. A detailed analysis of student preparation coupled with the comprehensive study of pre-course conceptual knowledge and misperceptions provided particularly rich and extremely informative data sets that are outlined in this paper. Additionally, students perceive that low stakes quizzing improve personal outcomes more than the targeted, collaborative and active modules and iPod applications, but traditional test scores indicate all three enhance certain student learning outcomes when at least two are present. The entire suite of MSE iPod applications developed for this project (Concept Questions, Vocabulary, Basic Knowledge, Tune-Up, Material Properties, Composite Calculator, MSE Convert, MSE Knowledge Tools and Review) is described in detail. The supporting web site for the project is currently under development, is concept mapped based, built upon student input/assessments, and targeted to address known conceptual difficulties in MSE. The concept map base for the project is reported in this paper. The paper concludes with a description of the remaining objectives for the iCollaborate project for the next academic year and further dissemination plans. At the conclusion of the project, all materials will be placed on the NSF sponsored National Science Digital Library (NSDL).

The National Science Foundation is supporting the project (NSF CCLI/TUES #0941012).

Introduction

The iCollaborate Materials MSE project is a comprehensive research program that has an overarching goal of improving student outcomes in introductory materials engineering courses. The project is multifaceted and includes several interwoven components, all of which are founded upon literature based best practices in STEM education research. The project components include: a detailed study of pre-course knowledge and misperceptions, an investigation of student preparation influencing course outcomes, an analysis of Index of Learning Styles (ILS) data, a switch to inductive teaching practices which include collaborative, active learning modules and concept/peer learning opportunities, collaborative writing of research papers, low stakes quizzing, the development of targeted iPod applications (Apps) that promote enhanced student understanding of known conceptual difficulties, MSE vocabulary terms, visual and conceptually contained presentations of material properties, material calculators and conversion tools, and the development of a web site based upon concept maps. This paper focuses on previously unreported components of the iCollaborate project that were researched, analyzed or developed during the 2011-2012 academic year. Previous papers have reported upon research activities during the previous two academic years[1-4].

A major component of the project was to transform the fundamental structure in our basic materials engineering course from primarily deductive practice to a student-centered, Information and Communications Technology (ICT) enabled, inductive teaching and learning environment. The ICT technology employed in this project is the iPod Touch, but conceptually, the applications (Apps) can be ported to other smart devices. As an additional outreach activity we are in the process of determining whether the databases and question banks developed for this project can be utilized in web based Apps so that they are accessible from our project web site (currently under development). We felt that the web Apps would allow for wider and more generic accessibility rather than porting the iPod Apps to other smart devices, which are then tied to different development languages and are subject to differing licensing agreements. The web Apps will be designed to run on smart devices, as well as on laptops and desktop computers, thus, making them more widely available to others teaching basic materials engineering courses.

While a great deal is now known about more effective teaching practices in STEM education, many barriers exist to implementing them within individual courses, especially for those faculty within institutions with limited resources and having high teaching loads. The iCollaborate project was designed to lower many of these barriers. First, the multi-faceted approach outlined in this project is conceptually portable to other disciplines. Second, we designed the project so that only one device ($229) is needed per collaborative group to lower the overall ICT equipment cost needed to implement iCollaborate. We note that while the collaborative approach has worked well for student outcomes, we have found that many students desire additional practice work or practice time on the devices. We have observed that the students who request the additional practice are usually either strong students or struggling students. This was not at all obvious to us when we began our project, so we now know that the web site that will accompany this project is not only a repository of information from the project, it will also provide the vital additional practice time needed for struggling students. While the outcome for the strong students has been more in the depth of their understanding, the students who struggled with the course have benefited the most overall from the iCollaborate approach. Finally, we built the Apps so that they will accommodate different content by only switching out the data sets and data decks, thus, making them useful beyond the materials engineering community. Finally, a carefully researched project that has been tested in "real" classroom environments may have a better chance of being adopted elsewhere as the inherent risks perceived with change by others is well understood and can be better controlled.

STEM Research Base

The iCollaborate project combines many known best practices in STEM education in novel ways and includes targeted, outcome based ICT support. Collaborative learning, active/inquiry learning, concept learning, peer learning, problem/case-based learning, low stakes quizzing, mini-lectures with just-in-time reading, and constructive alignment are all important components of our multi-dimensional approach. While this research base has been previously reported,[1-4] a summary of the research justification is presented here so that those not familiar with the iCollaborate project have an overview of its conceptual underpinnings.

All the principles implemented in the project are supported by theory based in cognitive and social constructivism; and, there is a substantial body of evidence that favors the inductive approach over the traditional deductive approach in engineering education[5-13]. This research indicates that students build scaffolds from existing cognitive structures to new information when there are connections to existing knowledge. All of the modules, mini-lectures and problem sets that have been developed as part of this project are designed to build these scaffolds by connecting new fundamental MSE principles to the existing knowledge base of our students, which was determined from mining several years of data and information from pre-course concept questionnaires, exams, and quizzes. Targeted modules, which connect to the students' existing knowledge base, are very important in an interdisciplinary field such as materials science and engineering. Known misperceptions are targeted in each project component as well.

Additionally, it is known that cooperative learning is an effective method of enhancing instruction [5-23]. "Between 1924 and 1997, over 168 studies were conducted comparing the relative efficacy of cooperative learning. These studies indicate that cooperative learning promotes higher individual achievement than do competitive approaches … "[15]. "The meta-analysis (of cooperative learning) demonstrates that various forms of small-group learning are effective in promoting greater academic achievement, more favorable attitudes toward learning, and increased persistence through STEM courses and programs"[19]. We modeled our collaborative work after the work of Johnson and Johnson [14-15, 17-18, 23-24] to include the elements needed for cooperative efforts to be more productive than individual efforts: "clearly perceived positive interdependence; considerable face-to-face interaction; clearly perceived individual accountability and personal responsibility to achieve the groups' goals; frequent use of relevant interpersonal and small-group skills; and frequent and regular group processing of current functioning to improve the groups' future effectiveness".

Another important component of the iCollaborate project is conceptually based peer learning. Mazur has shown that conceptually based peer instruction is an effective way to improve student outcomes in physics[24]. Peer teaching and concept learning has also been researched in materials engineering[25-28]. We have observed that a group, which is composed of only weak or only strong students, seems to impede the learning process and leads to difficult group dynamics.

There is also a research base to support our approach with ICT support in distributed cognition and collaboration. "Distributed cognition is a way to understand how people interact with their environment and how they can be enabled by the environment to undertake highly complex tasks that would usually be beyond the abilities of the unassisted individuals"[29]. Vygotsky first examined activity theory in the 1930's. Later, Hutchins and many others have contributed to research in distributed cognition[29-35]. Additionally, there have been studies investigating why computers enhance student learning and results indicated that task engagement increases at conceptual levels, student self-regulation increases, and exploration is encouraged[32]. There is also research to support that peers and social interactions are important components of distributed cognition[35].

There is also a literature base supporting the use of self-quizzing and knowledge cards to improve student outcomes[35-46]. McDaniel's work shows that "in the context of an actual course that quizzing benefits learning, and that it does so much more than focused reading of targeted facts"[40]. "Quizzing with feedback (either going over the quiz in class, or allowing the students time to consider their answers and subsequently reviewing the graded quiz) provides a more positive learning outcome than multiple readings without quizzes"[42]. A study by Karpicke and Roediger found that "repeated retrieval practice enhanced long-term retention, whereas repeated studying produced essentially no benefit"[43]. Recite-Recall-Review has been reported by McDaniel to improve student learning and another advantage of this method is that it is under the learner's control"[44].

A more robust description of the research base that supports connections between ICT enhanced collaborative learning based upon active, conceptually contained explorations, cognitive and social constructivism, distributed cognition, and STEM enhanced student outcomes is reported in more detail elsewhere[1-2].

Analysis of Pre-Course Evaluations

For each quarter during the iCollaborate MSE project, the students completed a pre-course evaluation instrument consisting of 26 questions, in three broad conceptual areas (chemistry, basic physics/science knowledge, and hands-on/project learning). During this academic year, we finally accumulated enough data (180 students), so that we could analyze our instruments for statistically significant outcome differences (see Table 1 for student characteristics). An outside evaluator and assessment specialist (Dr. Phil Buly) completed the analysis of the data. For this part of the project, we placed the students in the course into four categories: engineering technology (ET) majors, industrial technology (IT) majors, science (SCI) majors, and non-science or technology majors (NSCIT). For the pre-course evaluation materials, we examined overall GPA, GPA in Chemistry, GPA in Mathematics, and the Index of Learning Styles (Felder's ILS[46-47]) data for each student for each question. A one-way ANOVA test with $p<0.05$ was used to evaluate statistically significant differences, except where IT and ET students only were compared. In those cases, a T-test with $p<0.05$ was used.

Table 1. Characteristics of MSE Students (sample size, 180 students)

Major	**Class**	**ILS A/R**	**ILS S/I**	**ILS VI/VR**	**ILS SE/GL**	**Overall GPA**	**Chem GPA**	**Math GPA**
ET=39% IT=30% NSCIT=16% SCI=16%	Soph.=12% Junior=47% Senior=39% Post B.=2%	ACT=59% REF=41%	SEN=67% INT=33%	VIS=89% VER=11%	SEQ=56% GLO=44%	Divided into 4 Equal Quartiles	A=20% B=48% C=32%	A=21% B=46% C=33%

We have previously reported that students entering our basic materials course have difficulty identifying the correct primary bond type that exists between two metallic atoms, and subsequently, others have found similar outcomes nationally[49]. We now understand that changes in the way college chemistry is structured likely accounts for the robust misconception held by our students that metals are bonded with either ionic or covalent bonds (the only two primary bond types now emphasized in an introductory chemistry course). When we examined this question in depth, we found that different types of students had more difficulty than others answering this basic question, with ET students scoring the lowest (34.5% correct) and SCI students scoring the highest (60.5% correct). This significant difference indicates that completing an entire year of chemistry, rather than just one introductory chemistry course, does impact pre-course knowledge of metallic bonding. Since it is unlikely that the MSE community will be able to impact the structure of chemistry programs, introductory MSE faculty should be aware that if their students take only one introductory chemistry course, they likely will not have a good understanding of metallic bonding and may also have a robust misconception that these bonds will be either covalent or ionic. For this question, GPA in the introductory chemistry class resulted in different outcomes as well, with 2.0 GPA students scoring the lowest (34% correct), as compared to 3.0 and 4.0 GPA students (48%, 44%). Interestingly, Intuitive (INT) learners scored higher (50%) than Sensing (SEN) students (39%). Not surprisingly, a science student, with a high GPA in Chemistry, who is an INT learner, had the overall best outcome. And, an ET student, with a low GPA in Chemistry, who is a SEN learner, needs the most support during conceptual change activities.

Chemistry GPA also influenced the ability of the students to name a ceramic material. Seventy-four percent of Chemistry GPA 4.0 students were able to name one ceramic material, while only 51% of the 2.0 students answered correctly. Overall GPA also was significant for this question, with students in the top quartile answering correctly 75% of the time, while the students in the lowest quartile answered correctly only 54% of the time. Overall GPA also influenced the ability of students to correctly identify a polymer. However, this time the top and bottom quartiles scored nearly identically (68% and 67%), while the middle quartiles scored only 50%, and 44%, respectively. We examined this result for ET and IT students only and found the same pattern. While we could not identify the precise reason for this perplexing result, we do know that many of the IT students who take this class have considerable experience in outside projects (Formula

SAE, for example) using plastics and epoxies. But, not having measured this type of project experience in student preparation, we leave this result as speculation.

When we asked students about their knowledge of ordinary glass (it is amorphous or crystalline), we found interesting statistically significant differences in the ILS data. Reflective (REF) learners answered correctly nearly twice that of Active (ACT) learners, 66% versus 38%, and INT learners answered correctly nearly twice that of SEN learners (67% versus 36%). When asked about which material classification contained the densest materials, REF learners answered correctly 88% of the time, as compared to ACT learners at 73%. In the same question Global (GLO) learners outscored Sequential (SEQ) learners, 87% compared to 73%. Major also influenced this outcome with NSCIT scoring 63%, while SCI majors scored 93%.

For the overall pre-course assessment, major did matter statistically in the overall outcomes, even though all the students have completed the same course pre-requisites in Chemistry, Mathematics, and Physics. The SCI students scored the best, with 50% correct overall and IT students scored slightly higher than ET students (55% versus 53%). And, VIS students outscored VER students 55% versus 48.5%. And, finally INT learners scored 56.7% versus 52.7%.

None of these findings are surprising overall. Nor do they predict learning style influence on outcomes. However, they certainly do reinforce what we know in the literature about students, student learning, and the complexities of instructional design. We do know that students come to our classrooms with different levels of preparation and that scores in pre-requisite courses do matter, but are not always perfect indicators that key information has been retained. Students enter our courses with a wide range of learning styles, and some pre-requisite information is retained or learned differently based on learning styles. And, for our course, there are high levels of VIS learners (89%). Overall, the students who enter our course tend to be SEN (67%), ACT (59%) learners and GLO (56%) learners, although individual course sections do vary. Perhaps the most important reason for doing careful pre-course assessment of student knowledge lies not in the understanding of learning styles, or pre-requisite scores, but in the contextual answers the students give. With these assessments every instructor can uncover what students retain from their previous coursework and that often, what they do not know is quite surprising. Sometimes, what they think they know is even more surprising, and their answers to these questions reveal important student misperceptions. At other times, their answers reveal keys to conceptual change. For example, most students do understand that a metal will become less stiff as temperature increases, but fail to correlate that understanding when the same question is asked in terms of the Modulus of Elasticity. Through exploration of the pre-course assessments, we linked the problem to the word elastic. In their life experiences, the word elastic means stretchy, as in an elastic band. So, in their real world experiences, the hotter an elastomeric material gets, the more it will deform. Therefore, even if the students know a material will get less stiff as temperature increases, their pre-conceived definition of the word elastic will often cause them to indicate the wrong direction for the Modulus of Elasticity as temperature increases. Based on our experiences, we recommend that every instructor should evaluate the pre-requisite knowledge of their students in key areas important to MSE course outcomes.

Additionally, when we aggregated the pre-course assessment into three broad categories, and we found that overall the students as a group answered only about half (54%) of these basic questions correctly. This result was surprising in that we believed most of the students would know most of the answers before we began the assessment as the questions are indeed very basic. The students overall performed the worst on the basic chemistry questions (only 44%), while they only did only somewhat better on the questions reflecting on hands-on learning (55%).

We also examined whether the students' scores in these three content areas made a difference in their performance on four low stakes quizzes and the two mid-term exams. Only one minor difference was noted on the first three quizzes in that on quiz three, the students scoring higher in basic science knowledge, scored higher than their peers. But, on quiz 4, student outcomes were different for those students scoring higher (upper 50%) on their pre-course assessment overall and in basic chemistry knowledge. This trend is also true when only ET and IT students were evaluated. This result indicates that our course interventions as part of iCollaborate worked well on the first three quizzes, but not so well on the forth quiz. Quiz 4 is a complex design problem that also comprises a substantial portion of the first mid-term exam. And, indeed, the first mid-term exam shows the exact same differences. This statistically significant difference does not occur on the second mid-term exam. Since we are on the quarter system, it is somewhat difficult to divide the materials covered on each mid-term exam optimally. We believe this important key result illustrates two points. First, the iCollaborate interventions matter more than course preparation in the first three quizzes and second mid-term. But, work less effectively on the early complex design problem. This result also indicates that it is too early in the quarter for the students to make substantial gains with iCollaborate for design work. We also know that the placement of this design problem is not optimally placed within the first exam. But, given the constraints of the quarter system, there is little choice. However, we are considering how to restructure the problem so that the students can benefit more from iCollaborate within our time constraints (at least as much as they do on the other course components).

We also found interesting results by GPA when we aggregated the pre-assessments into the same three categories. Math GPA was significant in both the chemistry assessment, hands-on assessment, and overall. Overall GPA and Chemistry GPA were significant in the general science/physics knowledge assessment. Visual learners were outperforming verbal learners generally in all categories ($p<.15$), and statistically so in general science/physics and overall ($p<0.05$). This result is likely due to the high numbers of visual learners within the course, rather than any real measurement of ILS based outcomes. The IT students slightly outperformed the ET students in the hands-on part of the assessment ($p<.15$, but $>.05$). Each individual question on the pre-assessment was also evaluated by major type, ET versus IT students, but only one statistically significant result was found. The IT students correctly understood that stress levels did not change based upon material type in a diving board at nearly twice the rate of the ET students

(17% versus 10%). Again, we speculate that this outcome is based on the hands-on work many of the IT students do on projects outside the core curriculum. The ILS instrument measured ET students as SEN learners (69%), while IT students were 52% GLO learners. And the ET students outperformed their IT peers in Math GPA. It is interesting to note that on the question where the students are asked about metallic bonding, 12% of the IT students answer correctly, while only 9% of the ET students answer correctly. While this is not statistically significant difference, the low level of student knowledge regarding metallic bonding is stark. Other revealing answers include that 58% of all students believe polymers have the highest fracture toughness and 27% believe they are the hardest of all materials on the pre-course assessment.

iPod Applications

The following Apps have been developed for the iPod Touch platform: iCollaborate Vocabulary (Vocab), iCollaborate Basic Knowledge Building (BasicK), iCollaborate Concept Questions (ConQuest), skill tune-up (Tune-Up), a graphical Materials Properties application with list features (MSEMatProps), a unit conversion tool specific to units encountered in a basic MSE course (MSEConvert), a tool to calculate the Elastic Constant of Unidirectional composites (MSEComposites), and a study guide (MSEKnowledge Tools). All the Apps have been built and tested, except the MSEKnowledge Tools. The MSEKnowledge Tools App has been built for the iPod, but we are still working on the content for the study guides. Currently, we are now working on the web site that will accompany this project. The static content from all the Apps will be incorporated into the web site. And, web App versions of key iPod Apps are also under development so that they are available to a wider device audience.

Screen captures of the iCollborate Vocabulary App are shown in Figures 1-4. Figure 1 shows the conceptual topic titles that are common to many of the applications. We wanted all the applications to work in a similar fashion so that the Apps would have a common interface so that users can work seamlessly between applications. Figure 2 shows the vocabulary term in question (because this is the vocabulary application), but the Tune-Up and Knowledge Apps show basic questions and knowledge items appropriate to that application. In these Apps, the students flip the card to see if they have the correct answer (Figure 3). If their answer is incorrect, another screen shows with a more detailed explanation, a web link, and an audio explanation (Figure 4). In these apps, the students can work in either practice mode or test mode since these apps are designed to facilitate collaborative knowledge building. An extension of our project would be to build-in algorithms that would allow us to understand how the students are using these devices.

The concept question App (MSEConquest) was built with the same type of help for the user, but more in a multiple choice format so that we could display known misperceptions as multiple choice answers or have the students select different materials choices, also based upon common student misperceptions (Figures 5, 6). In this application, the students select an answer, and the correct answer displays as green (other answers display as red). We are currently looking in to adding the help feature to this App for incorrect answers based upon student feedback. However, as it currently stands, students rate this application as the most helpful in building their own knowledge when compared to the Vocab all and Tune-Up/Knowledge Apps. We speculate this is because the other two Apps contain information, which is readily available elsewhere.

In addition to the smart flash card and conceptual question type Apps, a number of other helpful apps have been built to support students enrolled in basic materials engineering courses. The MatProp app is especially useful to help the students gain conceptual understanding of material properties for different material classifications, and also as the students begin working on basic design problems for the quarter.

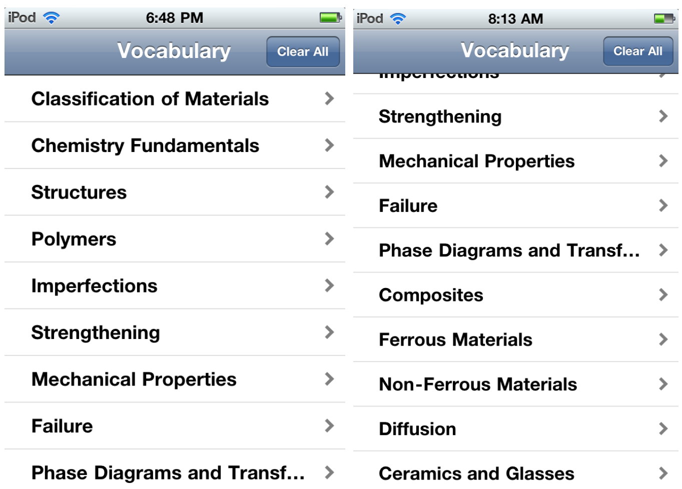

Figure 1. Screenshots of Conceptual Topic Titles

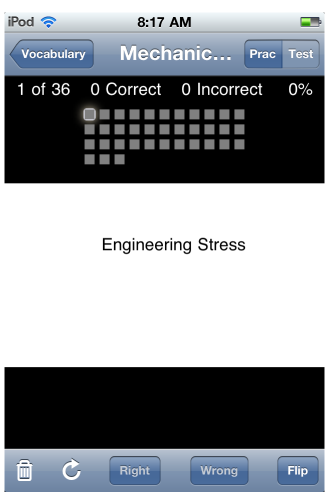

Figure 2. Screenshot of Card Topic

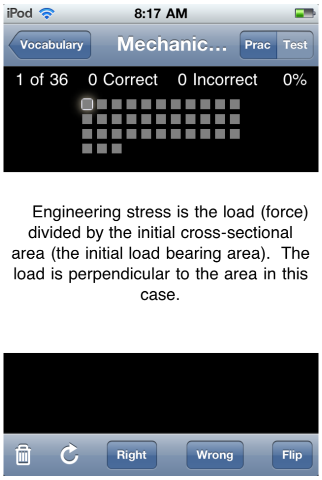

Figure 3. Screenshot of Correct Answer, User Interface

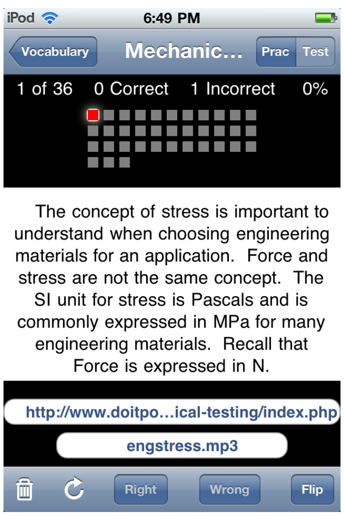

Figure 4. Screen Shot of Additional Help for Incorrect Answers

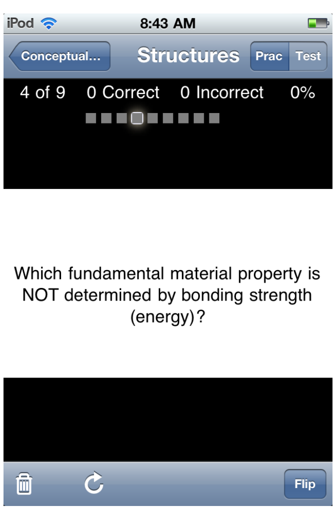

Figure 5. Conceptual Type Questions Work Differently

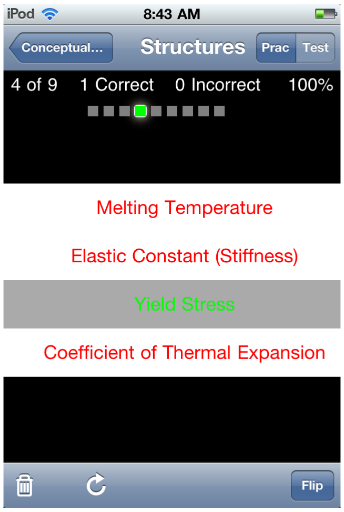

Figure 6. Conceptual Questions Include Misperceptions

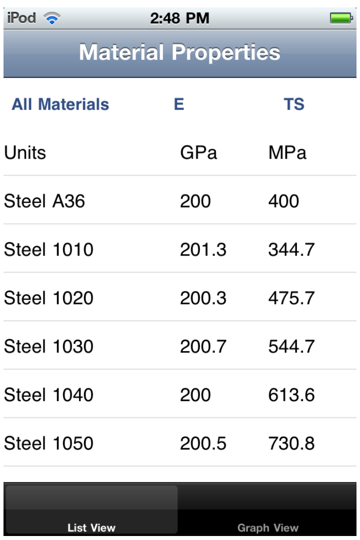

Figure 7. The List View of the MatProp App

Figures 7-9 show the basic features of the MatProp application. MatProp shows conceptually contained lists of material properties (Figure 7), as well as the ability to compare a material property of 6 different materials (Figure 8) or scatter plots of two different material properties for six different materials. The bar graph view (Figure 9) is more useful at the beginning of the term, but the scatter plot is more useful as the students begin their design work.

We also built a unit conversion program that was contained to units commonly encountered in basic materials engineering courses. While many unit conversion apps are on the market, we found they contained too many different types of units, and none had the suite of tools we needed for the course. A screen shot of the MSE Conversion App is shown in Figure 10. The units conversion areas are: mass, force, stress, density, temperature, length, area, volume, SI Prefixes, fracture toughness, specific heat, and thermal conductivity.

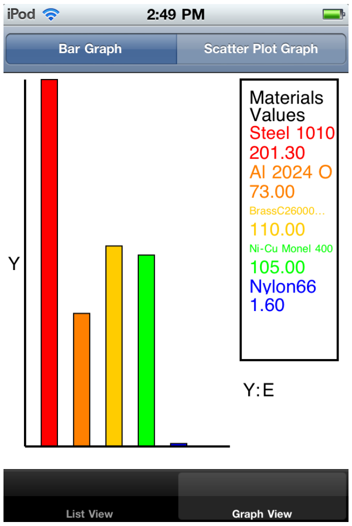

Figure 8. The Bar Graph View of the MatProp App

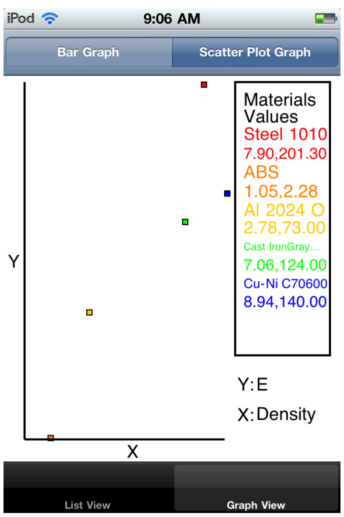

Figure 9. Scatter Plot Graph in MatProp App

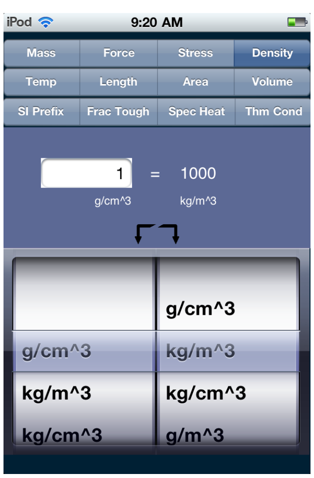

Figure 10. MSE Specific Unit Conversion App

We have also built an elastic constant, density, and volume fraction of fiber calculator App (Figure 11) for a unidirectional composite composed of a matrix and a unidirectional fiber. We have found this App useful to help the students understand the implication of fiber to matrix ratio. Finally, we are developing the content for the Knowledge Tools app. The App has already been built and we have assembled a great deal of content for it, but have not yet entered it into the app. This App will essentially be a study guide to the topics for a basic materials engineering course. The content will be open source and the students who have been working on the project have been key to identifying the content (Figure 12 shows the organization of the App only).

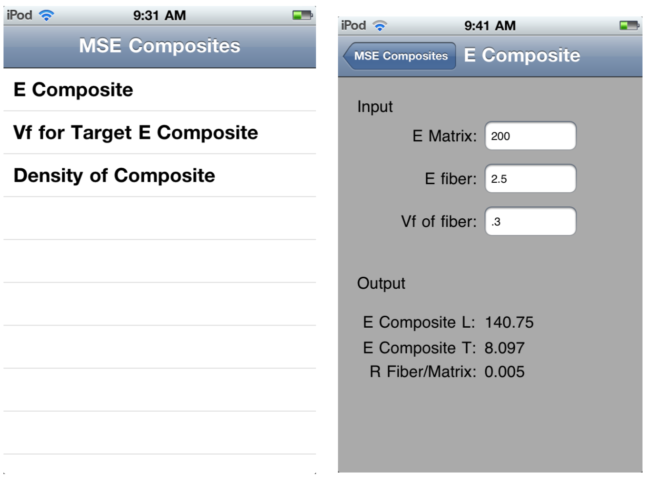

Figure 11. Unidirectional Composite Calculator for E and Density

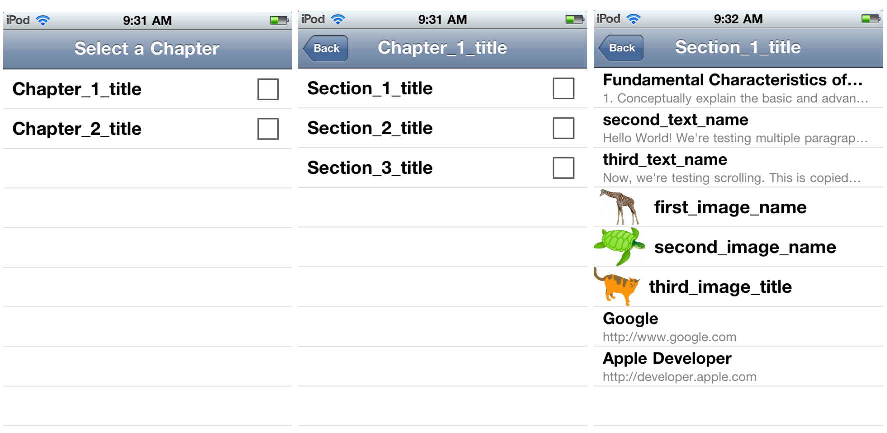

Figure 12. Organization of Study Guide App (Knowledge Tools) without Content

The web site for the project is currently under development. Based upon the formative assessment data, student focus groups, and other forms of student input, the web site for the course will be concept map based. The students told us in many different ways that it is difficult for them to make all the connections necessary to be successful in the course without an understanding of how the concepts map together. We also found that the web site needs to serve as a great place for students to gain additional practice time and to probe deeper into course concepts. Overall, the students wanted the web site to be part of the project and not a repository of information. We agree with them.

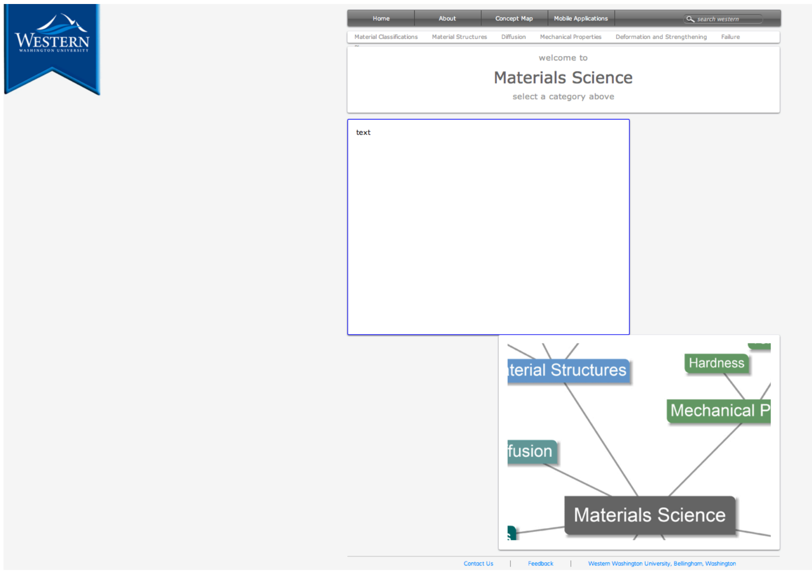

Figure 13. Overview of Web Site Under Development

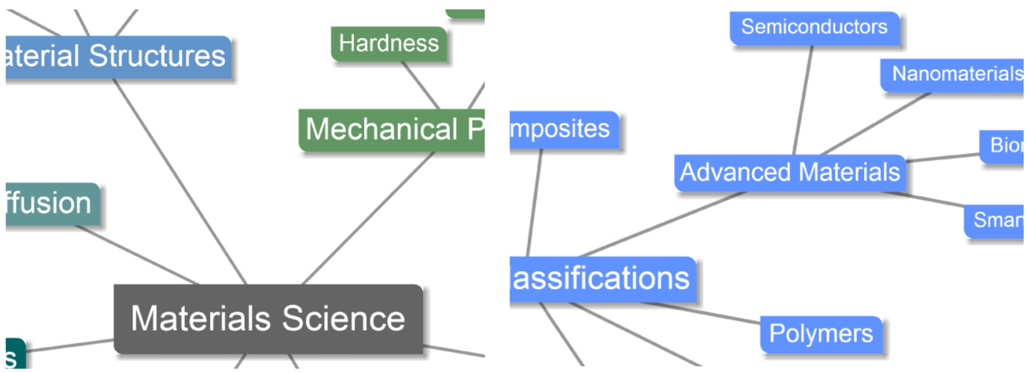

Figure 14. Screen Capture of Parts of Concept Map for Web Site

Overview of Feedback from Students

A detailed analysis of student feedback has been previously reported[1-4] and only an overview is given here. Overall, the students were able to understand the relationships between the collaborative assignments, the low stakes quizzes, and the mini-lectures in helping them learn different concepts in class. Since these items have all been designed to compliment and reinforce each other, it was very positive that most students readily found the connections. And, they did, more often than not, believe that their peers and the collaborative learning helped them. The structure of the course is deliberately only loosely correlated with the book. Students are assigned chapters for reading in the text, but the problem sets and modules deliberately take a much different approach to learning than the text does. The collaborative learning opportunities are conceptually targeted, designed to provide scaffolds to prior knowledge, and are active and inquiry based.

Formative feedback from our students has been invaluable in making iCollaborate more effective and useful. The students believe, and we agree, that a more effective way to run the course, especially given all our inductive practices, would be to have smaller discussion sections and/or senior level student support teams. Budget limitations preclude that as an option at this time. Some of the student feedback centered on our lack of firm connection to our chosen text. The iCollaborate project is designed so that any instructor or student in an introductory course will find it useful. However, most of the courses the students take at this time do not use inductive practice and are firmly tied to a text. At some point in the future, perhaps enough open access material will be available to make this issue non-existent. We made a number of changes to individual modules as we observed how the students interacted with them. A deep dive into outcomes on each quiz and exam with reference to where the information should be gained in the course is extremely valuable to any instructor, but was especially of value to us in this project.

The feedback from the students regarding the low stakes quizzing was extremely positive with more than 90% of the students finding them of value. The students are likely over valuing them because it is so easy for them to perceive a tie between the quiz and an exam score. The students feel the quizzes encourage them to complete the collaborative work. The students are right in that completing the collaborative work is necessary to do well on the quizzes, but the quiz is designed more to provide the individual accountability and mastery.

The interference feedback regarding the low stakes quizzes was helpful to us in refining their composition. Some students feel that the quiz content is repetitive, but we would use the word reinforce rather than repetitive to describe their purpose. The students who are asserting the quiz content is repetitive are the students who have definitely completed all the possible App and collaborative work. The students do raise an interesting research question about the number of times that concepts should be reinforced for optimum learning gains and in what form should the reinforcement be. In other words, do the students now have too many resources to support them? Likely the weakest students need more reinforcement opportunities, while the strongest students are likely to take more reinforcement opportunities. We do know that the project has enhanced student engagement and increased course completion rates. Because of all the collaborative work and low stakes quizzing, it is difficult for a truly engaged student to fall behind.

The top contributions of the collaborative activities relate to an improved content understanding. Two contributions specifically addressed the value of gaining insights from peers. Only one interference mentioned the difficulty of working with peers. Team members do evaluate each other at the end of the term and we are careful to balance teams by GPA and major. As with all collaborative work, some teams have difficulty getting all members to participate fully and sometimes divide the work rather than collaborate on the work. Only one team of the forty plus teams thus far became so dysfunctional that a team member was essentially working on their own because their team mates excluded the individual and the individual rarely came to class. Five students of the 180 have chosen not to work collaboratively, except on their term long research papers. Accommodations were made for various private reasons.

The wealth of responses from our students has been an indication of just how engaged they were in their own learning and the excitement of the project itself. Students perceive that low stakes quizzing improve personal outcomes more than the targeted, collaborative and active modules and iPod applications, but traditional test scores indicate all three enhance certain student learning outcomes when at least two are present based upon overall scores. We are currently evaluating the actual gains made in the courses with respect to the specific targeted student learning outcomes by individual test question target. Probing this information will allow us to further understand how students are performing and, more importantly, why each intervention supported the outcome or not and for how many students.

Conclusions

We have been very productive during this project. All of the Apps that we have promised to build have been built and tested (with the exception of the Knowledge Tools, which has only been built). We have a team of productive and knowledgeable undergraduate students who have been working with us, on the App building, web site construction, and the content. The final glitches need to be removed from the Apps. And, we must find a way to move the Apps to the Apple Store for free distribution rather than keeping them on development devices. The content for the Knowledge App will be added next summer. The web site to accompany the project is being built. We are currently investigating web based versions of the Apps for further dissemination. No other smart device platforms are being developed. An additional project would be to revise the code to understand how the students use the iPods in their own learning. The pre-course concept questions were analyzed and we also uncovered additional student misperceptions and language related misunderstandings. We also plan to examine standard test outcomes by individual question and outcome.

It is clear that student engagement is certainly enhanced in our course and that the students are interested in providing good feedback to us to improve our project so that maximum student gains are obtained (and understood). Overall, the students find the low stakes quizzes and collaborative work valuable to enhancing their understanding of course material. Students consistently rate the low stakes quizzes as the most valuable program component, but it is unclear to us as how the quizzes would be effective without the collaborative work. Students desire more class time for collaborative work and to use the iPods, but because of limited resources at our university it is not possible to add small discussion sections with student assistants. Another additional project would be to use the iCollaborate methodology in totally on-line versions of the course, but considerable development work would be necessary. Overall, our novel multi-faceted approach to inductive teaching and learning appears promising and our research is working toward understanding how best to improve student learning outcomes in introductory MSE courses.

Bibliography

1. Kitto, K.L. and Jusak, D. S., "The iCollaborate MSE Project - 2012, ASEE Annual Conference, NSF Poster Session, San Antonio, TX, June 2012.
2. Kitto, K.L. and Jusak, D. S., "Work in Progress – iCollaborate Project Update 2012, Frontiers in Education Conference, Seattle, WA, October 2012.
3. Kitto, K.L. and Jusak, D. S., "The iCollaborate MSE Project, ASEE Annual Conference, NSF Poster Session, Vancouver, BC, June 2011.
4. Kitto, K.L. and Jusak, D. S., "Work in Progress – The iCollaborate Project, Frontiers in Education Conference, Rapid City, SD, October 2011.
5. Prince, M. and Felder, R., "Inductive Teaching and Learning Methods", Definitions, Comparisons, and Research Bases", *Journal of Engineering Education*, April, 2006, pp. 1-16.
6. National Research Council Commission on Behavioral and Social Sciences and Education, *How People Learn: Brain, Mind, Experience and School,* Commission of Behavioral and Social Sciences and Education, Washington, DC, National Academy Press, 2000 (on-line free access, http://books.nap.edu/books/0309070368/html/).
7. Svinicki, M., "Synthesis of the Research on Teaching and Learning in Engineering Since the Implementation of ABET Engineering Criteria 2000", National Academies, https://www7.nationalacademies.org/bose/1DBER_Svinicki_October_Paper.pdf .
8. Felder, R., "Learning and Teaching Styles in Engineering Education", *Engineering Education*, 78(7), 1988, pp. 674-681.
9. Felder, R., and Brent, R., "Understanding Student Differences", *Journal of Engineering Education*, 94(1), 2005, pp. 57-72.
10. Prince, M., and Felder, R., "The Many Faces of Inductive Teaching and Learning", *Journal of College Science Teaching*, March/April 2007, pp. 14-20.
11. Prince, M., "The Case for Inductive Teaching", *ASEE Prism*, October 2007, pp. 55.
12. Felder, R., Woods, D., Stice, J., and Rugarcia, A., "The Future of Engineering Education II, Teaching Methods That Work", *Chem. Engr. Education,* Vol. 34, No. 1, 2000, pp. 2-21.
13. Briggs, M., Long, G., and Owens, K., " Qualitative Assessment of Inquiry-Based Teaching Methods", *Journal of Chemical Education*, 88(8), 2011, pp. 1034-1040.
14. Johnson, D., Johnson, R., and Smith, K.A., "Cooperative Learning Returns to College: What Evidence is There That it Works?", *Change*, July/August 1998, pp. 27-35.
15. Johnson, D., Johnson, R., and Smith, K., *Cooperative Learning: Increasing College Faculty Instructional Productivity*", ASHE-ERIC Report on Higher Education, Washington, DC, The George Washington University, 1991.
16. Smith, K., "Cooperative Learning: Effective Teamwork for Engineering Classrooms", Frontiers in Education Conference, 1995, Session 2b54.
17. Johnson, D. and Johnson, R., "An Educational Psychology Success Story: Social Interdependence Theory and Cooperative Learning", Educational Researcher, Vol. 38, No. 5, pp. 365-379.
18. Johnson, D., Johnson, R., and Stanne, M., "Cooperative Learning Methods: A Meta-Analysis", http://www.co-operation.org/pages/cl-methods.html, May 2000.
19. Terenzini, P. Caberra, A., Colbeck, C., Parente, J, and Bjorkland, A., "Collaborative Learning vs. Lecture/Discussion: Students' Reported Learning Gains", *Journal of Engineering Education*, Vol. 90, No. 1, 2001, pp. 123-120.
20. Kinzie, J., Gonyea, R., Shoup, R., and Kuh, G., Chapter 2, "Promoting Persistence and Success of Underrepresented Students: Lessons for Teaching and Learning", *New Direction for Teaching and Learning*, Issue 115, 2008, pp. 21-38.
21. Springer, L., Stanne, M., and Donovan, S., "Effects of Small-Group Learning on Undergraduates in Science, Mathematics, Engineering, and Technology: A Meta-Analysis", Review of Educational Research, 1999, 69, 21, DOI 10.3102/00346543069001021

22. Johnson, D., Johnson, R., and Smith, K., *Cooperative Learning: Increasing College Faculty Instructional Productivity*", ASHE-ERIC Report on Higher Education, Washington, DC, The George Washington University, 1991.
23. Johnson, D., and Johnson, R., "Making Cooperative Learning Work", *Theory into Practice*, Vol. 38, No. 2, Building Community Through Cooperative Learning, Spring 1999, pp.67-73.
24. Mazur, E., **Peer Instruction: A User's Manual**, Benjamin Cummings, 1996.
25. Krause, Decker, Niska, Alford, and Griffin, "Identifying Student Misconceptions in Introductory Materials Engineering Classes", *American Society of Engineering Education, Annual Meeting, Proceedings*, 2004.
26. Jordan, W., Cardenas, H., O'Neal, C., "Using a Materials Concept Inventory to Assess an Introductory Materials Class", *American Society of Engineering Education, Annual Meeting, Proceedings*, 2005.
27. Newell, J., and Cleary, D., "Using an Undergraduate Materials Research Project to Foster Multidisciplinary Teaming Skills", *Journal of STEM Education*, Vol. 5, Issue 1 and 2, Jan. – June 2004, pp. 18-23.
28. Angeli, C., "Distributed Cognition: A Framework for Understanding the Role of Computers in Classroom Instruction and Learning", *Journal of Research on Technology in Education*, Vol. 40, No. 3, 2008, pp. 271-279.
29. Trelease, R. B., "Diffusion of Innovations: Smartphones and Wireless Anatomy of Learning Resources", *Anatomical Association of Anatomists*, Vol. 1, November 2008, pp. 233-239.
30. Morgan, M., Butler, M., Power, M., "Evaluating ICT in Education: A Comparison of the Affordances of the iPod, DS and Wii", Ascilite, 2007, Singapore
31. Morgan, M., Brickell, G., and Harper, B., "Applying Distributed Cognition Theory to the Redesign of the "Copy and Paste" Function in Order to Promote Appropriate Learning Outcomes", *Computer and Education*, Vol. 50, 2008, pp. 125-147.
32. Karasavvidis, I., "Exploring the Mechanisms Through Which Computers Contribute to Learning", *Journal of Computer Assisted Learning*, Vol. 19, 2003, pp. 115-128.
33. Karasavvidis, I., "Activity Theory as a Conceptual Framework for Understanding Teacher Approaches to Information and Communication Technologies, *Computers and Education*, April, 2009.
34. Kim, Y. and Baylor, A., "A Social-Cognitive Framework for Pedagogical Agent as Learning Companions", *Educational Technology Research and Development*, Vol. 54, No. 6., December 2006, pp. 569-596.
35. Dede, C., "Transforming Education for the 21st Century: New Pedagogies that Help All Students Attain Sophisticated Learning Outcomes", Commissioned by the NCSU Friday Institute, 2007, http://www.tdhah.com/site_files/Teacher_Resources/MUVE/MUVE%20Documents/Dede_21stC-skills_semi-final.pdf
36. Gardenfors, P. and Johansson, Cognition, Education, and Communication Technology, Routledge, 2005.
37. Marra, R. and Bogue, B., "Women Engineering Students Self Efficacy – A Longitudinal Multi-Institution Study", http://www.x-cd.com/wepan06/pdfs/18.pdf
38. Akl, R., Keathly, D., and Garlick, R., "Strategies for Retention and Recruitment of Women and Minorities in Computer Science and Engineering", http://www.cse.unt.edu/~rakl/AKG07.pdf
39. Tindall, T., and Hamil, B., "Gender Disparity on Science Education: The Causes, Consequences, and Solutions", *Education*, Vol. 125, Issue 2, 2004.
40. Glenn, D., "Close the Book. Recall. Write it Down", The Chronicle of Higher Education, May 1, 2009.
41. McDaniel, M., Roediger, H., and McDermott, K., "Generalizing Test-Enhanced Learning From the Laboratory to the Classroom", Psychonomic Bulletin and Review, Vol. 14, No. 2, 2007, pp. 200-206
42. Klionsky, D., "The Quiz Factor", Letter to the Editor, CBE Life Sciences Education, *American Society for Cell Biology*, Vol. 7, No. (3), 2008, pp. 265-266.
43. Karpicke, J. and Roediger, "The Critical Importance of Retrieval for Learning", *Science,* 15 february 2009, Vol. 319, No. 5865, pp. 966-968.
44. Cutrim, E., Rudge, D., Kits, K., Mitchell, J. and Nogueira, R., "Changing Teaching Techniques and Adapting New Technologies to Improve Student Learning in and Introductory Meteorology and Climate Course," *Advances in Geosciences*, Vol. 8, 2006, pp. 11-18.
45. McDaniel, M., Howard, D., and Einstein, G., "The Read-Recite-Review Study Strategy, Effective and Portable", *Psychological Science*, April, 2009.

46. Felder, R. and Solomon, B., “Learning Styles and Strategies”, 1993 revision.
47. Zywno, M., “A Contribution to Validation of Score Meaning for Felder-Soloman’s Index of Learning Styles”, *Proc. ASEE Annual Conference*, June 2003, Session 2351.
48. National Academy of Engineering, Developing Metrics for Assessing Engineering Instruction: What Gets Measured, 2009.
49. Krause, S., Kelly, J., and Baker, D., “Addressing Misconceptions and Knowledge Gaps in Restructuring of Atomic Bonding Content in a Materials Course to Enhance Student Conceptual Change”, ASEE Annual Conference, Vancouver, BC, 2011.