AC 2012-4279: THE ICOLLABORATE MSE PROJECT - 2012

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The iCollaborate MSE Project – 2012

Abstract

This paper describes the progress to-date on the various components of the iCollaborate MSE [Materials Science and Engineering] project, as well as the preliminary assessment data that has been collected. The overall objectives of the research are to measure if improvements in student learning outcomes, student engagement, and course completion rates are possible if the structure in a basic materials engineering course is transformed from primarily deductive practice to an Information Communication Technology (ICT) enabled inductive teaching and learning environment. There are two major components of this research project. The first element is the change in the course form from deductive to inductive practice. The second element of our project tests ICT devices (iPod Touches) to facilitate collaborative, conceptual, and peer learning, along with basic knowledge acquisition for individual learners.

In the new class format, students complete conceptually targeted problem sets each class meeting and term-long research papers in collaborative groups. Additionally, there are ample opportunities for concept questions, peer learning, case studies, and low stakes quizzes. MSE education applications for the iPod Touch have been built to support collaborative as well as peer learning and self-evaluation quizzing. In-class concept quizzes, mini-lectures, and just-in-time reading assignments are important components of the new learning environment. Student progress is tracked with pre- and post-course concept questionnaires, scores from traditional exam questions, a conceptual scoring rubric for the term-long research papers, and successful course completion rates.

We have found that the standard multi-touch interfaces of the iPod are relatively easy for students to use. With the iPod Touch it is easy to switch among vocabulary practice cards, concept questions, basic knowledge "tune-up" questions, and explorations of materials properties, the periodic chart, or practice unit conversions. The materials within the applications are conceptually contained so that while exploration and higher order connections are still encouraged, the students are not overwhelmed with choices. The multi-media format of the iPod Touch allows applications that accommodate different student learning styles. To date the following applications have been built: Vocabulary, Concept Questions, Tune-Up, Basic Knowledge, Material Properties, Convert, Composite Calculator, and we are building the content for the completed MSE Knowledge Tools application.

We are collecting data sets that will allow us to evaluate the research questions initially posed. The baseline data set for the project is for a section of the course that was taught in a primarily deductive environment with individual research projects. The second baseline type data set is for a course section inductively taught with students completing collaborative, learning objective targeted problem sets, and in-class quizzes. The next data sets are to be collected with iPod Touch support in various inductive practice configurations. Overall, there were improved student learning objective outcomes between the first two data sets. We anticipate further gains in subsequent datasets.

Additional sections of the course will be taught in different inductive practice configurations to determine the effects of the different inductive practice elements on outcomes. Data sets one and two show no significant difference overall in student preparation for the course.

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Introduction

The overall objectives of the iCollaborate MSE project are to research whether improvements in student learning outcomes, engagement, and course retention rates are possible for all students, but especially those from traditionally underrepresented groups, if the structure in basic materials engineering courses is transformed from primarily deductive practice to an ICT enabled inductive teaching and learning environment. The ICT technology employed in this project is the iPod Touch, although our MSE applications (apps) will readily run on iPads as well. Conceptually, the approach is easily ported to other smart devices, and the databases and question banks that have been generated as part of this project will be available to others and will be widely disseminated. The MSE education apps for the iPod Touch are designed to facilitate and support collaborative learning modules, which target specific student learning objectives known to be challenging for students in introductory MSE courses. Additionally, the iPod Touch apps draw information from a server in contained data sets, so they are highly customizable and adaptable for local needs. It is a simple matter to add or delete questions, concepts, or vocabulary terms. It is also straightforward to change deck or chapter labels and rearrange cards. Similarly, the MatProp App is customizable for different datasets of materials, and materials and properties can be added or deleted from the decks quickly.

We speculate, that students in courses without lab components, such as ours, or those students taking on-line courses, should especially benefit from our multi-faceted approach. All of the concepts that are proposed as part of the project are based upon research findings from STEM education research (described below). The plan is to disseminate the MSE apps through the Apple App store, but currently they run only on our many iPod test devices during the development and testing phase of the project because of Apple's development licensing restrictions. At the conclusion of the project, all materials will be placed on the NSF sponsored National Science Digital Library (NSDL).

While much is known about more effective practices in STEM education, many barriers exist to implementing them within individual courses, especially in institutions with limited resources and high teaching loads. Faculty are reluctant to use untested new methods or modules in their own classrooms. And given tight and demanding review schedules, it is also risky. The research and development work we are completing during this project is designed to lower those barriers for other faculty. The multi-faceted approach outlined in this project is conceptually portable to other disciplines, as only the databases need to be exchanged in the flashcard part of the MSE apps. We designed the project so that only one device ($229) is needed per collaborative group, so the equipment cost is modest for the ICT support. But, we have found in our alpha and beta tests that while the students will indeed work collectively in groups to work with the devices, many of them desire an additional, personal device for practice work they wish to do that goes beyond the goals set by their teams. We view this as positive, but it will certainly drive up the overall cost of deploying the devices. Certainly part of the issue is that students already view their own iPods as personal and not shared devices. While it is good for the students to spend more time on individual devices, it is important not to lose the collaborative approach that is integral to improved student learning outcomes, while accommodating these individual needs and requests. We have observed that the students who request the additional iPods are usually either strong students or struggling students. This was not at all obvious to us when we began our project.

STEM Research Base and Project Outcomes

This foundation for our project is built upon the many known best practices in STEM education research, but combined in novel ways and also includes 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. All the principles implemented in the project are also 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 [1-8]. While this research base has been previously reported [9], a summary of the research justification seems necessary here to conceptually understand the project.

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 the students. We have found that it is very difficult for the students to make these important connections by reading some existing textbooks. Pre-course concept questionnaires have uncovered surprising student misperceptions and knowledge gaps, which are also targeted in the modules and mini-lectures. For example, students come to the course without a good understanding of the elastic modulus and an incomplete understanding metallic bonding, even when they completed pre-requisite courses in both physics and chemistry. Existing texts assume a level of understanding of bonding that does not coincide with measured student pre-course knowledge, nor the fundamental methods used today in introductory chemistry courses. Similarly, introductory texts assume the students fundamentally understand that a high elastic means that a material is very stiff, while in fact, many of the students understand the word elastic to mean stretchy, so a high elastic constant means a highly stretchable material. There are many known misperceptions and knowledge gaps in basic MSE courses, so it is imperative to develop targeted and effecting scaffolding exercises and modules. Targeted modules, which connect to the students' existing knowledge base, are equally important when building new conceptual knowledge, especially in such an interdisciplinary field as materials science and engineering.

In cognitive constructivism, experiences lead to knowledge (which is highly influenced by prior learning) and, similarly, in social constructivism language and interactions with others leads to the connections. Additionally, it is known that cooperative learning is an effective method of enhancing instruction [10-18]. "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 … " [10]. "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" [14]. The outcomes of our research, thus far, confirm the successful student learning outcomes of the collaborative approach and, also, seem to indicate that collaborative learning can be supported in a number of ways: modules targeted to eliminate student misperceptions, as well as targeted, conceptually contained ICT support apps. We modeled our collaborative work after the work of Johnson and Johnson [10-11, 13-14, 18-19] 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" [10-11, 13-14, 18-19]. We too found that all these elements are necessary for effective collaborative work, whether or not, the work is supported by ICT devices. In our new course, the students meet each class period with their groups to complete active, concept driven collaborative exercises. Weekly low-stakes quizzes are absolutely necessary to add individual and personal accountability to the collaborative work component. Team evaluations are also absolutely necessary for accountability. We have found that collaborative work must be completed each (or most) class session for positive interdependence. The term-long research project is scored with both collaborative (interdependence) and individual accountability elements. We interviewed one student who had failed the course when it was taught deductively, but did very well the second time through the course when it had transformed to the inductive teaching and learning environment (both offerings were taught by the same instructor). The student told us that the targeted, collaborative learning modules and the ability to work through challenging assignments with others throughout the term accounted for the change in outcome from his perspective. Additionally, the in class, low-stakes quizzes forced him to keep up with course materials, but disappointing his collaborative group team members appeared to be even more motivating.

Another important component of our project is conceptually based peer learning. When students who understand the concepts explain those concepts to other students, it not only helps the weaker students understand concepts, but explaining gives the stronger students a deeper conceptual understanding [21]. Mazur has shown that conceptually based peer instruction is an effective way to improve student outcomes in physics [21]. Peer teaching and concept learning has also been researched in materials engineering [22-24]. We have found that it is important to carefully consider the make-up of student groups both in collaborative learning and peer learning. We have tried various methods to form groups as part of this research project. It seems, by observation, that peer and collaborative learning is most effective when the groups are diverse and not larger than three, although we are still in the process of collecting data to support that speculation. 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.

Distributed Cognition in Support of Collaborative and Peer Learning

The support of classroom environments with computer technology is not new, nor are the theories associated with distributed cognition. However, we proposed that the combination of an inductively taught collaborative classroom environment plus a multi-touch, multi-functional, group "personalizable" support device offered new and different opportunities to stimulate cognitive development and enhance student outcomes. Having now observed the students in the alpha and beta tests of the devices and witnessed the different level of student engagement in our inductive course environment leads us to believe the multi-dimensional approach in our project may indeed stimulate cognitive development and improve learning. And, our very preliminary assessment data is encouraging.

In our MSE apps, when the student enters an incorrect answer, the apps provide support for the student by showing a more detailed explanation, a link to more information, and an audio explanation of the concepts. For the students, the ability to find additional and reliable information and resources is very important. The ready access of information is changing the way in which students acquire information. Students do want to explore information, but it is important to pre-evaluate sources for them so that exploration leads to learning and not distraction. Additionally, we found it necessary to turn-off and secure all the distracting features of iPod Touches (pictures, game center, iTunes, etc.). We have found many excellent existing internet resources for MSE and by embedding them as links within concept questions, knowledge acquisition questions, and vocabulary terms, resources can be used quickly and just-in-time and not lead the students to searching the web on their own endlessly. Our apps are distinguished from traditional flashcard apps in that when a student answers a question incorrectly, our apps provide support to help students reconstruct and build knowledge scaffolds. Incorrect answers lead to detailed conceptually based explanations, audio files, and web-links. It is imperative that the students are given more support than "your answer is wrong" and it must be linked to important concepts. Incorrect answers in the apps include known student misperceptions.

iPods are popular with students and the standard multi-touch features of the interface are very easy to use, so the barriers between the use of the device and students are few. Although the standard interface was somewhat frustrating to our student app developers, the student users intuitively understand the features (swiping, button touches, selection, etc.). In our initial releases of our own apps, we found only a few students not already well versed in the platform, and even for those students, the learning curve seemed small. However, we did find it is important to make sure the students are familiar with the capabilities and functionality of each app and we need to find ways to make them more integrated into the collaborative exercises. Students often assume they know how to run the apps, especially our Mat Prop app, and miss important functionality. Multiple MSE apps on each iPod makes it easy for each group to switch among peer learning and concept questions, exploration of materials properties or materials structures, recall flash self-quizzes or web investigations. In addition, the materials data sets within those applications are conceptually contained so that while exploration and higher order connections are still encouraged, the students are not overwhelmed with thousands of materials choices and no contextual basis for judgments. Because the device is wireless, we found the that the capacity of our campus wireless routers to accommodate a large number of simultaneous users in our classroom somewhat vexing as the number of smart device users on campus has risen dramatically during our project. In the alpha deployment of the apps, all devices were readily accommodated within the classroom on campus wireless. However, in the beta release of the apps, not all devices could log-on when exactly when the groups needed them. We have switched the class to a different location, but the issue points out that the campus infrastructure must be robust enough to support the number of devices needed to support large class sizes. The multi-media format of the iPod Touch allowed us to create apps that support different student learning styles (as measured by the Felder/Soloman Index of Learning Styles, ILS in our project). There is every reason to assume that the next generation of iCollaborate MSE could include external students in the collaborative groups. There is no reason to assume that on-line or off-campus students could not be integrated into the learning experiences of the on-campus class. The latest Operating System (OS) from Apple includes "Face-Time" capabilities and MSE the apps we developed already run on iPads, so facilitating such interactions is readily available.

We also found a few applications, which have been built by others, that support the student learning outcomes and engagement opportunities we need for our project. For example, we added the powerful Wolfram Alpha data-mining engine to our suite of apps. We found that resources like the Khan Academy and Wolfram Course Assistants are superior to anything we could create to bridge the learning gaps in conceptual knowledge, especially in basic mathematics and chemistry. We have found the visual displays in The Chemical Touch Lite app (free) for atomic mass, density, atomic radii, and melting point to be particularly good as we cover theoretical density and structure relationship. And, "The Elements" app (which is linked to Wolfram Alpha) is especially robust for the periodic chart and crystal structure explorations. EleMints: The Periodic Table app is the only periodic table app we found that shows different atomic radius values for a particular element and includes the important metallic radius (others are empirical atomic radius, calculated atomic radius, covalent radius, and Van der Waals radius).

There is also a research base to support our approach 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 [24].

Vygotsky first examined activity theory in the 1930's and argued for the idea that cognition requires activity, but that the tools we use in those activities fundamentally change cognition. Although Edwin Hutchins was one of the main developers of distributed cognition in the 1980s many others have contributed to research in distributed cognition [24-30]. 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 [27]. There is also research to support that peers and social interactions are important components of distributed cognition. "Further, the types of representations available in mediated interaction … are richer and more nuanced than those possible in face-to-face settings without ICT" [29]. One report emphasized that 21st century students must have the ability to interact meaningfully with tools that expand mental capacities (distributed cognition), understand collective intelligence (where knowledge is pooled), multitask, appropriate, simulate, perform, play, use judgment, network, negotiate and have the ability in transmedia navigation (the flow of information across multiple modalities) [30].

There have also been many reports in the literature supporting the use of self-quizzing and knowledge cards to improve student outcomes [31-41]. "When students study on their own, "active recall" — recitation, for instance, or flashcards and other self-quizzing — is the most effective way to inscribe something in long-term memory" [35]. McDaniel's work shows that "in the context of an actual course that quizzing benefits learning, and that it does so more than focused reading of targeted facts" [36]. "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" [37]. Similarly, Karpicke and Roediger recently reported that "repeated retrieval practice enhanced long-term retention, whereas repeated studying produced essentially no benefit" [38]. Flash cards have been shown to positively influence student outcomes in the geosciences [39]. "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" [40]. This work suggests that knowledge building in the form of self-quizzes can help students improve on exams and one of the project investigators has measured the effectiveness of "practice quizzes" in a materials engineering course. In-class quizzes are still an important component of this project, but are separate from the iPod apps. We speculate that both are necessary to improve outcomes. The preliminary assessment information presented later in this paper indicates the students believe this to be so as well.

Thus, there is a robust 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.

Feedback from Students and Lessons Learned

Students from the alpha and beta test of the applications have provided the feedback, thus far, for the project. In the alpha deployment cycle, the apps were not all that well integrated into all the course activities as we had just made the shift to all collaborative learning, peer learning, and low stakes quizzing the prior quarter as part one of the project. In the alpha deployment, thirty five students from the course participated in a 50 minute, semi-structured focus group interview on conducted by the outside reviewers for the project (note: individuals will be named after the blind review). The focus group interview sought data on the impact of three novel pedagogical approaches being implemented. Students first shared answers in peer groups of 2 to 5. A class share time allowed all responses to be heard and clarified and these were recorded on the white board. Finally, the students had the opportunity to individually rate each item. This provided a quantitative measure of the class' level of agreement with each statement. Student feedback from the three questions for the alpha focus group interviews is as follows.

Question #1: In what ways did the **in-class collaborative exercises** contribute or interfere with learning the course content?

Tables 1 and 2 quantify the students' statements in terms of contributions and interferences regarding the in-class collaborative activities. The scale was from 1 to 5, with 1 being "Not at all" and 5 being "To a great extent". The statements in the table are ordered from the highest to lowest mean rating. The percent of students who responded with a 4 "true for me" and 5 "true to a great extent" is also included.

Table 1. Alpha App Test Group – Contributions of Collaborative Work

Contributions of collaborative activities	N	Mean	SD	% 4 or 5
1. Chance to rework problems was good	**27**	**4.5**	**.6**	**93%**
2. Good practice for the low stakes quizzes	**27**	**4.4**	**1.0**	**85%**
3. Assignments reinforced ideas from the lecture	**26**	**4.2**	**1.1**	**81%**
4. Peers helped develop my understanding	**27**	**4.0**	**.9**	**74%**
5. Targeted different learning styles	**27**	**3.9**	**1.2**	**63%**
6. Helped familiarize with the textbook	**27**	**3.6**	**1.3**	**63%**
7. Provided good opportunity to use the apps	**27**	**3.3**	**1.3**	**52%**

We were especially encouraged that the students could grasp the relationships between the collaborative work, the low-stakes quizzes, and the mini-lectures. Since these items have all been designed to compliment and reinforce each other, we were pleased to see the students agreed and found the connections. And, they did, more often than not, believe that their peers and the collaborative learning helped them, and they were able to pick out some connections to learning styles targeted (this is surprising). Since the apps were not well integrated into the collaborative work, we agreed with the students on this point. It is still not clear to us whether to completing integrate the support or include some apps as stand-alone support. 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 than the text does, for the many reasons outlined above. The collaborative learning opportunities are conceptually targeted, designed to provide scaffolds to prior knowledge, and are active and inquiry based.

Table 2. Alpha App Test Group – Interferences of Collaborative Work

Interferences of collaborative activities	N	Mean	SD	% 4 or 5
1. Too much time waiting for help	**27**	**3.1**	**1.1**	**37%**
2. Spreadsheets had too much number crunching	**27**	**3.0**	**1.2**	**41%**
3. Book didn't complement the problem set	**25**	**2.8**	**1.4**	**32%**
4. Spreadsheets took focus away from concepts	**27**	**2.8**	**1.3**	**26%**
5. One group member did the work, but all got credit	**27**	**2.3**	**1.3**	**27%**
6. Too much repetition of concepts	**26**	**2.3**	**1.1**	**11%**

The feedback from the students regarding interferences provided us with opportunities for reflection and adjustments. Given the size of the class and support budgets for the course, it is difficult to see what can be done to reduce class wait time for help. A more effective way to run the course, especially given all the other inductive practices, would be to have smaller discussion sections and/or senior level student support teams. Because our approach is different than the text, we were not surprised that the students felt the lack of connection to the text. Some of the students thought a longish spreadsheet exercise involved too much practice, perhaps not realizing how much it helped them to be successful in a complex, biomedical design module immediately following the spreadsheet. Upon reflection, we deleted two of the material choices on the exercise, but kept the spreadsheet exercise largely intact for the next cycle.

Question #2: In what ways did the **in-class practice quizzes** contribute or interfere with learning the course content?

Tables 3 and 4 quantify the students' statements in terms of contributions and interferences regarding the in-class practice quizzes. Again, the scale was from 1 to 5, with 1 being "Not at all" and 5 being "To a great extent". The statements in the table are ordered from the highest to lowest mean rating. The percent of students who responded with a 4 "true for me" and 5 "true to a great extent" is also included.

Table 3. Alpha App Test Group – Contributions of In-Class Low-Stakes Quizzing

Contributions of low-stakes quizzes	N	Mean	SD	% 4 or 5
1. Quizzes were relevant to course content	**25**	**4.5**	**.6**	**96%**
2. Encouraged us to do the problem sets	**23**	**4.4**	**.7**	**92%**
3. Good alignment of content between problem sets, quizzes, and tests	**24**	**4.4**	**.7**	**91%**
4. Quizzes were concept-oriented (good)	**24**	**4.2**	**.8**	**88%**
5. Take home quizzes good since no time limit	**24**	**4.1**	**.9**	**75%**
6. Encouraged students to keep up with the readings	**24**	**3.9**	**1.2**	**79%**

The feedback from the students regarding the low-stakes quizzing was extremely positive. Overall, there were six low-stakes quizzes during the term (quarter system), with one of them being a rather long design problem. As shown in Table 3, more than 90% of the students find them of value, and can see the alignment among the various course components. It is somewhat interesting that 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. It is interesting that many of the students understand these important intersections, but, of course, not versed in course design. They just understand that it helps them be successful.

Table 4. Alpha App Test Group – Interferences of In-Class Low Stakes Quizzing

Interferences of in-class practice quizzes	**N**	**Mean**	**SD**	**% 4 or 5**
1. Need more variety in the format of quiz items (too many T/F items)	**20**	**2.9**	**1.4**	**40%**
2. True/false questions didn't reflect the problem sets	**24**	**2.7**	**1.4**	**29%**
3. Quiz content was repetitive	**24**	**2.5**	**1.1**	**13%**
4. Increased test anxiety for the course	**24**	**2.1**	**1.2**	**21%**

The interference feedback regarding the low-stakes quizzes was helpful to us in refining the components needed for the next cycle of our research program. We did rely on T/F items for many of the quizzes as we did not want to take away too much class-time to administer the in-class quizzes. But, we did refine the quizzes to include other question forms such as multiple-choice and fill-in-the blank, but kept the time allotted to them roughly the same. Indeed some students feel that the quiz content is repetitive, but we would use the word reinforce rather than repetitive to describe the purpose. We were concerned about the number of students who felt that the quizzes increased test anxiety. In response to this concern, we allowed the students to drop the lowest two quizzes, for final grade calculations. We feel that the concern regarding the T/F questions not reflecting the problem sets we likely annoyance at the form of the questions, especially given that more than 90% of the students thought they aligned well in their earlier responses (see Table 3).

Overall, it seems the feedback from the students very much favored the use of individual low-stakes quizzes after collaborative problem sets and modules. 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. We have taken a novel multi-faceted approach in this project, all of which is based on sound STEM learning research. It is not entirely clear to us at this point, whether the resulting gains add together somewhat equally or whether there is one component that significantly outweighs others. And, we know that the answer to those questions will be different depending on the characteristics of the student. Likely the weakest students need more reinforcement opportunities, while the strongest students take more reinforcement opportunities, but the gains made by one group is different than the other group. We do know that the novel, multi-faceted approach taken in this project has certainly enhanced student engagement and enhanced course completion rates overall.

Question #3: In what ways did the use of **apps** contribute or interfere with learning the course content?

Tables 5 and 6 quantify the students' statements in terms of contributions and interferences regarding the use of apps. The scale and ordering of the responses are the same as in the previous two questions and is not repeated here.

Table 5. Ratings of Alpha App Test Group – Contributions of Apps

Contributions of the use of Apps	N	Mean	SD	% 4 or 5
1. Concept questions gave good feedback (i.e. answers in different ways)	**27**	**4.1**	**1.0**	**74%**
2. Mat Prop app was helpful	**27**	**4.0**	**1.0**	**78%**
3. Apps reinforced the important concepts	**27**	**4.0**	**1.1**	**67%**
4. Content of Vocab app was helpful	**27**	**3.9**	**1.1**	**67%**
5. Concept questions relevant to test material	**27**	**3.9**	**1.1**	**63%**
6. Good repetition/reinforcement of concepts	**27**	**3.7**	**1.1**	**59%**
7. Easy to look up Mat Properties	**26**	**3.7**	**1.3**	**65%**
8. Apps helped me to do well on the tests	**27**	**3.7**	**1.2**	**56%**
9. Additional information (provided by the apps) was interesting	**26**	**3.5**	**1.2**	**58%**

Given the circumstances of our alpha deployment of the apps, we were encouraged by the positive response from the students. First, we deployed the apps immediately after the quarter in which we switched to entirely the collaborative, inductive practice teaching environment. This previous course was the quarter where we gathered the second data set, inductive methods, but without the apps. Needless to say, there were many changes for us all to integrate and understand. Also, we knew the apps were not well integrated into the collaborative experiences because we were unsure whether the campus wireless system had the capacity to deploy the devices at once and because the apps, after all, were untested in an actual course. We did not want the students or the apps to fail because of circumstances we could not control. We continue to see that the students prefer the Concept app and Mat Prop all above others as we have continued our deployment cycles. This seems somewhat obvious to us now, but was not apparent when we began our project. The students value the Concept (question) app because it contains information not available in the text or otherwise readily accessible. While the Vocab app and the Tune-Up app contain information more accessible to them. As we said previously in this paper, smart devices have changed the way in which students view and acquire information and facts. The Mat Prop app is unique and contains information not readily available in that same form without much more work. And, our ILS data sets, show that the students in our courses are mostly visual learners. It was interesting to see that the students did, however, find the Vocab app, useful as a quick and reliable way to review for the exams and learn new terms. There are more vocabulary words in the Vocab app than in the text, which we designed on purpose to engage in materials engineering beyond the confines of the text, but these added terms do seem to annoy some students who are only interested in learning something if it is going to be on the test.

Table 6. Alpha App Test Group – Interferences of Apps

Interferences of the use of Apps	N	Mean	SD	% 4 or 5
1. Apps need to show if you completed each step or item	**27**	**4.5**	**0.8**	**89%**
2. Flash card app had bugs (kick you out, can't go back, etc)	**26**	**4.2**	**1.0**	**81%**
3. Mat Prop app was slow	**27**	**4.0**	**1.0**	**74%**
4. Need better user interface for all apps	**27**	**3.9**	**1.1**	**70%**
5. One iPod per group is not enough	**27**	**3.8**	**1.2**	**70%**
6. Names of the apps too long/difficult to read	**27**	**3.6**	**1.3**	**56%**
7. Not enough class time to use apps	**27**	**3.5**	**1.3**	**56%**
8. More concept questions would be helpful	**27**	**3.5**	**0.9**	**52%**
9. Easier and quicker to get information from the book	**24**	**3.5**	**1.4**	**50%**
10. Difficult to access apps off campus	**27**	**3.3**	**1.6**	**56%**
11. Need better overview of how to use apps (in the beginning of the quarter)	**25**	**3.3**	**1.5**	**60%**
12. Better organization of apps	**24**	**3.1**	**1.4**	**42%**
13. Better wording on the apps needed (words hard to read)	**25**	**3.0**	**1.3**	**40%**

The students gave us terrific feedback on the apps, which we used to improve the apps during the following summer. The most important one for the flashcard type apps was that it was difficult for the students to tell whether they had completed a deck or not. Almost everyone wanted this feature so we added it. The students now see a check mark on the opening page of each deck if it has been completed. And, the students can delete the mark to redo a deck. We added seamless switching between practice mode and test mode to compliment the change. We added a feature set to email the results to others, whether it be team members or instructors. Our project version, however, sends the data to a confidential, secure location on a server. The revised apps also have a swipe feature to move forward and back at any time.

Additionally, we spruced up the interfaces and tried to eliminate as many bugs as possible. We made many significant improvements on the Mat Prop app and feel that at this point it is quite good with regard to usability and interface design. We added more concept questions and will continue to do so. We are continually adding materials and properties to the database. A student is currently reviewing all the wording on each page of each app from a student perspective to make the pages as helpful and accessible as possible.

Our outside reviewers provided the following summary to us (again after the blind review their names will be added. "Overall, the contributions recognized by the students for questions one and two (the use of collaborative activities and in-class quizzes) outweighed the interferences. The percentage of agreement for the contributions ranged from 52% to 96% compared to interferences' range of 11%- 40%. In addition, themes emerged from the list of contributions while interferences were more disjointed (though still valuable to understand).

In particular, 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. Many of the contributions for the in-class quizzes identified the relevancy of the quizzes to important concepts. Two mentioned that the quizzes were motivation to keep up with other class tasks.

Examining the statements for question 3 (the use of app), it is apparent that most reference a particular app and the results paralleled the separate study done on apps. This is problematic when trying to draw conclusions for the impact of apps in general. When administering the next focus group, the question will be revised so that the class responses consider specifically the impact of all apps on learning.

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Table 7 Alpha Cycle - Overview of Apps (N=35)

To what extent was the following App helpful with learning the course content? (listed highest-lowest mean)	**Mean** (1=not at all) (5=to great extent)	**Pct. Responses "4" or "5"** (helpful or greatly helpful)
4. The **Materials Property app**	4.1	77%
3. The **Concept Question app**	4.0	70%
2. The **Vocabulary app**	3.9	69%
1. The **Basic Knowledge app**	3.4	41%

Table 7 summaries the overall ratings of each of the apps during the alpha deployment of the devices. After examining these results and reexamining the educational apps now in the Apple App store, we decided that we would not continue to develop the Basic K app, which is focused on providing extra support for basic mathematics and chemistry concepts. As noted earlier, the Khan Academy apps and the Wolfram Course Assistant apps provide a much more robust and rich support structure than we could ever build.

Next the students were asked about specific features of the apps. In the following section our responses are within brackets and italicized.

What features of the Vocabulary app were helpful and what could be improved? (N=29) Categories of Responses: (#of responses) and quotes bulleted to elaborate

Helpful

(10) Repetition helped study, listed all important vocab

- *The vocab was kinda of helpful, because of the vast amount of the vocab*
- *The vocab app was helpful in assessing my understanding of vocabulary before the exams*
- *Just that it will take you through all the important vocab*

(5) Flashcard format was good, instant feedback

- *Instant feedback on flash card style answers was helpful*
- *Simple, it works, easier substitute to flashcards*

(3) Provided explanation if wrong *[This is wrong, we do, of course. This was a bug in one app only.]*

Suggestions to improve

(3) Answer always "true" *[This is incorrect and regarded a bug in one app.]*
(2) Need search feature, being able to go back and forth without deleting or starting over
(2) Need to be able to have record of completed questions *[Added]*
(2) Poor presentation, visuals, interface *[Improved, but not intended to be flashy.]*
(1) Freezes, slow load time *[This is a wireless issue.]*
(1) Some vocab repeated between chapters *[Note: this was designed on purpose.]*
(1) Vary the difficulty, questions fairly easy *[Most students do not agree.]*

What features of the Basic Knowledge app were helpful and what could be improved? (N=23) Categories of Responses: (#of responses) and quotes bulleted to elaborate

Helpful

(8) Helped reinforce basic concepts

- I liked how this app reviewed stuff that we learned in chemistry, but had probably partially forgotten
- Helpful in looking up info., but not crucial.
- Reinforcement of concepts picked up in text

Suggestions to improve

(4) Never used
(3) Poor interface, buggy
(2) Not sure what this app is

(2) Need to be able to have record of completed questions
(1) More questions
(1) Fix T/F
(1) Didn't apply to learning
(1) Being able to go back and forth without deleting or starting over
(1) Concept app was more effective

What features of the <u>Concept Question</u> app were helpful and what could be improved? (N=22) Categories of Responses: (#of responses) and quotes bulleted to elaborate

<u>Helpful</u>
(9) Tested knowledge, reinforced learning
- *These were nice because they actually tested my knowledge*
- *Good quiz/test practice*
- *Overall a great way to grab concepts and ideas*

(5) Good Questions
- *Thinking in the form of a question supported and diversified learning process*
- *Very helpful, different than book questions- so solidified concepts*
- *I liked how the concept questions had choices for the answers rather than just the flash card format. I liked the combination of flash cards and these multiple-choice cards.*

(2) Provided explanation if wrong

<u>Suggestions to improve</u>
(4) Need to be able to have record of completed questions *[Added]*
(3) More Questions *[Added]*
(2) Never used
(2) Need search feature - Being able to go back and forth without deleting or starting over *[Added]*
(1) Too easy *[Most students do not agree.]*

What features of the <u>Materials Property</u> app were helpful and what could be improved? (N=29) Categories of Responses: (#of responses) and quotes bulleted to elaborate

<u>Helpful</u>
(9) Fast, easy way to look up prop
(4) Helpful with assignments, problem sets
(2) Good list of props
(1) Ability to compare props

<u>Suggestions to improve</u>
(6) Slow *[Greatly improved now.]*

(3) Hard to use, poor interface *[Greatly improved and easier.]*
(3) Hard to find Prop – need to be able to change prop without scrolling to top *[Added]*
(2) Never used it, the book was easier *[Not if one uses all the features.]*
(2) More props
(1) Fix T/F
(1) Need to be able to have record of completed questions
(1) Had too much data
(1) Put on Blackboard so we could look it up anytime

Tables 8 through 12 shows the feedback from the beta test cycle of the apps with the revisions from the alpha app test cycle included. For the most part, this round of feedback is similar to the feedback from the first alpha deployment cycle. It should be noted that we did eliminate the test anxiety component from the low stakes quizzing by allowing students to drop their lowest two scores (4 of 6 are counted). The drawback to that approach is that some students chose to skip quizzes. In the current offering, the students will only be able to drop non-zero scores on both the homework and the quizzes.

Table 8. Beta Deployment - Contributions of In-class Collaborative Activities

#	Statement	% 4 or 5 *Agree or Agree to great extent*	Mean
10	Worksheets were good preparation for the quizzes / tests because they had a consistent structure	88%	4.5
3	Help from instructors as well as peers	83%	4.1
6	Practice the lecture ideas right away while it's still fresh in your head	83%	4.2
7	Better to do problems in class than at home	71%	4.0
1	Discussion benefited those who don't understand as well as those explaining	69%	4.0
8	More likely to tackle all the problems, accountability	65%	3.8
13	Could resubmit all the worksheets	63%	4.0
4	Group members have a different approach to problems, and your understanding will be deeper	57%	3.7
12	Collective effort is incentive to be actively engaged and contribute to learning	51%	3.6
2	Apply knowledge to real life applications and questions, not just theory	49%	3.5
5	Repetition leads to confidence and enjoyment of the problem process	49%	3.3
11	Chance to practice communication skills	37%	3.2
9	As you collaborate you can show what you know	35%	2.8

The wealth of responses from this group of students is an indication of just how engaged they were in their own learning and the excitement of the project itself. We switched classrooms to have better access to a more robust wireless system, but gained a much smaller room as a result and some students find the noise in the classroom distracting. Overall, we did not solve the wireless access problem. If anything, access was worse. The number of smart devices is outpacing our ability to add access given the budget situations.

This section of students really liked to work in collaborative groups, so they didn't like it when they couldn't finish all their work during class-time. This issue is not easy to solve given our lack of financial resources. Holding smaller and longer discussion sections, of course, is the answer to this issue, but given the constraints of the system, it is unlikely we will be able to extend course time and hold discussion sections. The same concern, manifested in a different way, was also observed in the alpha deployment,

Table 9. Beta Deployment - Interferences of In-class Collaborative Activities

#	Statement	% 4 or 5 *Agree Agree to great extent*	Mean
17	Some assignments may not be finished in class	69%	3.8
14	Division of labor not always equal	60%	3.6
16	When didn't finish assignment in class, it was much more difficult to collaborate	60%	3.6
19	Everyone didn't have to understand all aspects of the problem	60%	3.4
15	Number crunching spreadsheets led to one person doing work	51%	3.4
21	Some of questions/ worksheets were confusing	43%	3.3
23	Some worksheets had data that was not realistic	30%	2.8
18	Not conducive to all learning styles	29%	3.1
20	Could choose to rush through and do sloppy work	29%	3.1
22	Questions were open-ended and I left not being confident in answer	24%	2.8
24	Can get distracted by noise of groups and difficult to stay focused	19%	2.4

Table 10 indicates that almost all the students find the low-stakes quizzing valuable and is consistent with the results from the alpha deployment (Table 3). The ratings in the beta cycle were somewhat higher in all aspects since we incorporated changes based upon the concerns from the alpha cycle. The higher ratings likely reflect higher student satisfaction with the quizzes (more question varieties and the ability to drop low scores) than actual philosophical content of the quizzes.

The students in the beta deployment still rated the apps as contributing less to their understanding of the course. This is not surprising since the apps are still not all that well integrated into course activities because of the issues we are having with our wireless system on campus. If a student group cannot gain access to their apps and it delays their work, the students are rightfully annoyed and it detracts from the perceived value of the app. The collaborative nature of the apps for practice is also ruined if the app cannot join the network at the appropriate time. It is just more difficult for the students to work in their collaborative groups outside class time and find a wireless access point as well. If the students are frustrated with the device access, it does not matter how effective the content is. Rightfully, they feel tools need to work on-demand.

Table 10. Beta Deployment - Contributions of In-class Quizzing Activities

#	Statement	% 4 or 5 *Agree* *Agree to great extent*	Mean
34	Acted as good study guides for the exam	97%	4.7
31	Good incentive to learn material; grades depended on quizzes	91%	4.4
37	Consolidated what information was important to learn	91%	4.5
32	Kept you from trying to learn material right before test, no cramming	88%	4.3
33	Questions were based off what we learned from homework and lecture	85%	4.3
35	Gave good accurate feedback from the grading; good gauge of comprehension	85%	4.2
43	Had enough time to complete	82%	4.2
40	Weighted fairly towards your grade	79%	4.0
42	Reinforced what was done in collaborative portion of class	73%	4.0
39	Added individual aspect to learning process	59%	3.6
36	Immediate feedback	53%	3.7
38	Added individual aspect to your class grade	53%	3.5
41	Exciting and confidence building, reinforced what was done in collaborative portion of class	38%	3.1

Table 11. Beta Deployment - Interferences of Low-Stakes Quizzes

#	Statement	% 4 or 5 *Agree* *Agree to great extent*	Mean
50	Comprehensive understanding was required to receive a good score	61%	3.5
44	On spreadsheet quizzes they were calculations exercise rather than conceptual learning	56%	3.6
48	Based on memorization	30%	3.1
47	Not enough time to fully understand concept before we were tested on it	27%	2.6
45	How the quizzes were weighted could have been better	15%	2.3
46	Preparing for the quiz took time away from the reading assignments	15%	2.4
49	Material on the quizzes wasn't timed well with the lectures	15%	2.4

Table 12. Beta Deployment - Contributions Course Components

#	Statement	% 4 or 5 *Agree* *Agree to great extent*	Mean
59	The In-class Practice Quizzes contributed to my understanding of the course content	91%	4.6
58	The In-class Collaborative Activities contributed to my understanding of the course content	79%	4.2
60	The use of Apps contributed to my understanding of the course content	39%	2.9

Conclusions

After two cycles of implementation of our multi-faceted approach to our inductive teaching and learning systems, we have learned a great deal about how its various components should be implemented. 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). We are currently evaluating the actual gains made in the courses with respect to the specific targeted student learning outcomes and that data will be available for the conference. 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. Issues with wireless network access is hampering our ability to fully utilize our iPod apps in the classrooms, but the students engage in the devices at many other times successfully. Students desire more class time for collaborative work and to use the iPods, but without additional resources, it is impossible to add discussion sections at our university currently. 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.

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