AC 2011-1274: THE ICOLLABORATE MSE PROJECT

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The iCollaborate MSE Project

Abstract

The overall objectives of the research proposed in the iCollaborate MSE [Materials Science and Engineering] project are to measure if improvements in student learning outcomes, student engagement, and successful course completion are possible if the structure in basic materials engineering courses are transformed from primarily deductive practice to an Information Communication Technology (ICT) enabled inductive teaching and learning environment. The specific innovations that are proposed in the project are the development of MSE education applications for the iPod Touch that are designed to facilitate and support collaborative learning exercises which target specific student learning objectives which are known to be challenging for many students in MSE courses. It is hoped that the combination of specific learning objective targets, completed in collaborative groups, and supported by conceptually contained data, visuals, audio, and information from the iPod Touch, will lead to specific improvements in outcomes for students.

The support of classroom environments with computer technology is not new, nor is the idea that distributed cognition improves learning. However, the combination of a collaborative environment with a multi-touch, multi-functional, group "personalizable" device affords new opportunities to stimulate cognitive development to enhance student outcomes. The devices are popular with students and the multi-touch features in the interface are easy to use, so the barriers between the use of the device and students are negligible. The applications written for the iPod Touch make it easy for each group to switch among peer learning vocabulary and concept questions, exploration of materials properties, recall type self-quizzes or web investigations. In addition, the materials within the applications are conceptually contained so that while exploration and higher order connections are still encouraged, the students will not be overwhelmed or have no contextual basis for judgments. The multi-media format of the iPod Touch will also allow applications that accommodate different student learning styles. One of the grand challenges of engineering (National Academy of Engineering) is to advance personalized instruction/learning methods and there is no reason that collaborative groups should not be able to customize their own learning environments. Individual groups can continue their development outside scheduled class time since the applications will allow the groups to track their own progress as the applications operate in either practice or test mode.

But, important research questions remain. Are the new learn anywhere, multi-touch, multi-media devices going to change education in ways yet to be understood just as PCs and the internet have and continue to do so? What role will these smart, multi-touch devices play in distributed cognition? Can the devices facilitate collaborative learning? Will learning outcomes be different for the collaborative groups using these smart devices? Will their use engage students in new ways? What is the cognitive impact engendered of these devices in learning activities? This paper is intended as an overview of the iCollaborate MSE project, its theoretical foundation, which is based upon engineering education research, and the work completed thus far. The National Science Foundation is supporting the project (NSF CCLI Project 0941012).

Introduction

The overall objectives of the research proposed in iCollaborate MSE project are to research whether improvements in student learning outcomes, engagement, and course retention 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 Information Communication Technology (ICT) enabled inductive teaching and learning environment. In addition to the multi-faceted inductive transformation plan, the specific innovations that were proposed are to develop MSE education applications for the iPod Touch that are designed to facilitate and support collaborative learning modules which target specific student learning objectives which are known to be challenging for many students in MSE courses. It is hoped that the combination of specific learning objective targets within those modules, completed in collaborative groups, and supported by conceptually contained data, visuals, audio, and information from the iPod Touch, will lead to improvements in student learning, engagement and retention. If the research proposed in this CCLI project proves to be successful, faculty teaching other related courses could adapt and implement similar modules and iCollaborate applications for their own local environments. The iPod Touch modules draw information from a server in contained data sets, so they are highly customizable for local needs. We speculate, that courses without lab components, such as ours, should especially benefit from this approach. All of the concepts that are proposed as part of the project are well based upon findings from STEM education research (described below). While the iPod Touch is the ICT device used here because of its multi-touch and wireless multi-functional features, the applications software that will be developed could be easily translated to other smart devices. The MSE applications will be freely disseminated through the Apple Applications (App) store. At the conclusion of the project, all materials will be placed on the NSF sponsored National Science Digital Library (NSDL).

The number of smart device applications developed by professional educators is relatively small given that there are currently more than 300,000 applications for the iPod Touch/iPhone and approximately 10 billion application downloads have occurred through the Apple App store. We know that our "Gen Y" students are more ethnically diverse and much more engaged in multimedia and in socially connected ICT activities, so there is an extraordinary opportunity to engage them within higher education in new ways that we are yet to understand. No collaborative modules supported by free smart device applications exist yet for MSE education within engineering technology programs, nor have they been tested with rigorous STEM educational research to our knowledge. The iPod Touch modules are designed to be flexible so they can adapted to work with other modules or exercises.

While some pieces of what is proposed here already exist scattered in several different places, there is no easily accessible and time efficient way for faculty to integrate them together, and what modules exist have no free ICT smart device support. While much is known about more effective practices in engineering education, many barriers exist to implementing them within individual courses, especially in institutions with limited resources and high teaching loads. Faculty, rightly, are reluctant to use untested new methods or modules in their own classrooms. The research and development work that is to be completed during this project is designed to lower those barriers in basic materials engineering education, and it will make it possible for many others to transform their individual courses and the approach is conceptually portable to other disciplines. Since only one device ($229) is needed per collaborative group, the equipment cost is modest since the devices are available on a "check out" basis to the student groups. In addition to the collaborative problem modules, the iPod Touch applications take a number of forms designed to accommodate different student learning styles [we have used the Felder/Soloman Index of Learning Styles] and range from simple interactive self-quizzes that track of success, to databases of conceptually contained materials and materials properties grouped by use and classification (any of which singularly or in groups can be visualized graphically or in lists), concept questions with tracking, audio and visual files, and links to existing MSE education sites. The MSE modules and the iPod Touch applications will be adapted for use in high schools and outreach activities in the future. One of the modules will also be adapted for middle school activities. Currently, five applications have been developed and are currently in test mode.

STEM Research Base

Most of the elements of the known best practices in STEM engineering education research are present in the student-centered iCollaborate MSE project: cooperative learning, active/inquiry learning, concept learning, problem and case-based learning, and constructive alignment. All the principles that will be implemented are supported by research results in STEM education and educational 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]. Research indicates that deep learning takes place when students are able to build scaffolds from existing cognitive structures to new information when there are connections to existing knowledge. 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 [9-18]. "Between 1924 and 1997, over 168 studies were conducted comparing the relative efficacy of cooperative, competitive, and individualistic learning on the achievement of individuals 18 years or older. These studies indicate that cooperative learning promotes higher individual achievement than do competitive approaches … " [9]. "This is one of the largest bodies of knowledge in education or social psychological health." "… Although many teaching procedures have been recommended over the past 60 years, very few are still around. Almost none are as widespread and institutionalized into instructional practices as is cooperative learning." [12]. "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" [13]. "The research evidence itself indicates that a) the theories underlying cooperative learning are valid and b) cooperative learning does indeed work in college classrooms." [9] Engineering is fundamentally a cooperative enterprise where groups of individuals work together with specific project goals (with materials engineering being no exception), so intuitively it is no surprise that cooperative learning and team based approaches enhance undergraduate engineering education.

Engineering education research also indicates that individual learning styles must be considered in course structure/content and that assisting students understand their own learning styles (metacognitive awareness) is equally important.

Research findings "show that students learn by fitting new information into existing cognitive structures and are unlikely to learn if the information has few connections to what they already know and believe" [2]. The National Research Council (NRC) completed an in-depth study and reported on successful learning strategies [2]. This report and the work of many others [1-8] show that it is important to build upon the "conceptual and cultural knowledge that students bring with them to the classroom" [2]. A number of factors may contribute to the differences with one explanation being similar to that of effective peer teaching. 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 [19]. Mazur has shown that conceptually based peer instruction is an effective way to improve student outcomes in physics [19]. Peer teaching and concept learning has also been researched in materials engineering [20-22]. The research literature specifically indentifies several important features that must be present in any successful cooperative learning implementation. According to Johnson and Johnson [9-10, 12-13, 17-18] the following elements are necessary 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." [9-10, 12-13, 17-18]

Thus, there is a considerable research base that shows us that much is known on how to improve student learning outcomes, foster teaching enhancements, engage students more in their own learning and how to provide environments where all students, especially those from traditionally underrepresented groups, thrive. So, why is there still so much deductive practice in engineering education? Simply stated, there are still many barriers between faculty members wishing to switch to inductive practices and collaborative learning in their own classrooms. Even for those faculty members willing to move to new approaches much work and heavy time commitments are necessary. Because of the increased workload on faculty (both in direct contact time with students and research expectations), precious little time is left for classroom innovations. And, because of rigorous review schedules, faculty rightly worry that their own innovations might be considered unsuccessful. Thus, faculty need free access to proven, easy to adapt and implement educational modules and supporting ICT structural technologies. Lowering these barriers is absolutely essential for the widespread adoption of new effective practices in engineering education. This is one of the fundamental reasons for the CCLI (now TUES) program at NSF.

Distributed Cognition: ICT Support for Collaborative Learning

The support of classroom environments with computer technology is not new, nor are the theories associated with distributed cognition. However, we propose that the combination of a collaborative classroom environment with a multi-touch, multi-functional, group "personalizable" device affords new opportunities to stimulate cognitive development to enhance student outcomes. The devices are popular with students and the multi-touch features in the interface are very easy to use, so the barriers between the use of the device and students are negligible. The iCollaborate system with multiple MSE applications written for the iPod Touch 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. The multi-media format of the iPod Touch allows us to provide applications that accommodate different student learning styles (as measured by the Felder/Soloman Index of Learning Styles, ILS). Some students prefer lists, some visual display boxes, while others prefer graphically presented data, and some prefer audio presentations. Because the device is wireless, the students are also be able to draw upon outside resources as necessary. Each detailed correct answer has a link to a web resource, for example. The multi-touch format of these devices may facilitate active learning in ways that are yet to be understood. The popularity of such devices and their applications (almost 10 billion downloads to date) may indicate preferences for personally customizable devices and that these devices may indeed play a significant new role in education. One of the grand challenges of engineering from the National Academy of Engineering is to advance personalized instruction/learning methods and there is no reason that collaborative groups should not be able to customize their learning environments[23]. In the structure that is described here, groups and individuals can easily continue their work and development outside the normal class structure. Since the applications will allow the groups to track their own progress, there is no reason to assume the groups will all progress at the same pace or in the same way. Because of the widespread availability of software such as Webex, there is every reason to assume that the next generation of iCollaborate MSE could include external partners in the groups. Individuals within the collaborative groups can check out a different device if they need more time on task than others within their group.

Educational applications are appearing almost every day for smart devices, but include precious few solid or sound MSE related applications. However, there are several excellent periodic chart applications that we have found to be of particular relevance to this project. Chem Touch ($0.99) [or Chem Touch Lite (free)] is a touch periodic chart where the user can simply touch the element to see a detailed list of properties or select a visual display of the melting temperatures or densities painted in different colors across the screen. For any learner who prefers visual displays of data, the application provides unique opportunities for quick visual explorations that are simply not possible within other platforms. EleMints: Periodic Table ($4.99) displays different kinds of elements in different colors and provides excellent lists of the basic properties of individual elements (including the metallic radius and a number of other radius values, along with their definitions which is unusual for period chart apps). The Elements: A Visual Exploration for iPod 4 ($9.99) provides visually appealing displays of elements, properties, structures, and is tied to the powerful Wolfram Alpha data-mining engine. But, unfortunately, this application does not display the metallic radius. All three of these period chart applications are loaded on the iPod Touch devices.

However, most of the existing applications are either not for higher education or not written by professional engineering educators, although better quality applications are starting to appear. Computers have changed and will continue to change education [23-31]. A good previous example of ICT adoption and change ("the diffusion of innovation") in higher education was the "progressive, pervasive adoption of the personal computer, and the World Wide Web for anatomical informatics and educational use" [24]. "And now … conscientious innovators become "early adopters" of promising new technologies in order to communicate their appropriate uses and relative advantages … " [24]. "Yet, few of these [ICT] devices have been adapted for educational applications despite their significant interactive affordances and educational potential … each has a unique combination of affordances and therefore may lend themselves to the design of new forms of learning interactions and activities" [25]. As one researcher noted "that the rapid evolution of computer applications has lead to widespread adoption of new technology without a priori formal educational assessment … especially if they are readily embraced by the current "net" generation of students" [24]. But, important research questions remain. Are the new learn anywhere, multi-touch, multi-media devices going to change education in ways yet to be understood just as PCs and the internet have and continue to do so? What role will these smart, multi-touch devices play in distributed cognition? Can the devices facilitate collaborative learning? Will learning outcomes be different for the collaborative groups using these smart devices? Will their use engage students in new ways? Will the use of these new smart devices when coupled to collaborative learning modules improve outcomes for all students, including women and other traditionally underrepresented students? "What is the cognitive impact engendered by the use of these mediating artifacts in learning activities" ? [25] Will the applications and devices distract the students and move them off-task?

Certainly, "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. … and interactions in computer mediated learning environments should take into account the balance of cognitive loads …" [25]. 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 [27-31]. "The amplification or augmentation effects of learning with computers can then be most constructive and valuable, if they are situated and interpreted within a conceptual framework that can actually capture the intricacies of technology-enhanced classrooms as complex distributed cognition systems including humans, tools, and artifacts, along with their interactions" [23]. 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].

So, there is a 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. Here, though, the exploratory concept is testing the new smart, multi-touch multi-functional iPod Touch applications in a collaborative environment with collaborative modules to determine if these ideas improve specific targeted student learning outcomes, engagement, and successful completion/retention, especially for women and other traditionally underrepresented groups in engineering technology. In order to find out, detailed and careful assessment and evaluation is part of the iCollaborate project.

iPod Touch Applications

There have 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]. All this recent work suggests that knowledge building cards in the form of self-quizzes can help students improve on exams and one of the project investigators has seen 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.

There are several applications for the iPod Touch that let users submit their own flash cards and share them with others. These applications track the success of the responses and the users can take a card out of the system. It is readily apparent after reviewing these applications that university level students are sharing their study flash cards freely and that other students are using them in a large social structure. However, they are certainly not peer reviewed and are certainly not designed by professional educators. And, the cards occasionally contain incorrect information and other students "study" from the incorrect cards. But, it is certainly clear that there is a need to interject pedagogically sound applications into this rapidly developing world for knowledge building, self-quizzing based on sound pedagogical approaches by professional educators.

Application self-quizzes are divided into conceptually contained topic areas, show the correct answer, and the students flip for a more detailed explanation of the correct answer (both in written from and from a spoken audio track). A reference link to an available web resource is also given. Users keep track of successfully completed questions (visual display) and are able to move questions out of each concept deck. The BasicK (Basic Knowledge) deck is an application where the students are be able to review pre-requisite knowledge (chemistry terms and bonding, units, conversions, formulas, etc.) that we have identified as problematic based upon the results of previous pre-class concept questions. Every attempt is made to clarify known misperceptions within all the application decks.

Mazur's work in Physics[19] and a host of other STEM research[1-19] has validated the use of concept questions and peer teaching/learning in improving student outcomes and depth of conceptual understanding in STEM fields. Previously identified student misperceptions are included as choices for the tested concept questions as we have found that helping the students understand why a certain concept is wrong is extremely important in creating new scaffolds. Each answer provides a conceptual answer why the selection was wrong, rather than just telling the students their choice was wrong. Additionally, the students have an audio explanation for clarification and a web link for further explanation. Audio explanations cover known student misperceptions in more detail. For example, students must rebuild their knowledge base in chemistry to include the important, to materials engineering education, metallic primary bond. But rebuilding this context requires a great deal more than just telling the students their answers are incorrect. The students must actively make this new connection, more than once.

The currently built conceptual overview of topics is as follows: Classification of Materials; Chemistry Fundamentals, Structures, Polymers, Imperfections, Strengthening, Mechanical Properties, Failure, Phase Diagrams and Transformations, Composites, Ferrous Materials, Non-ferrous Materials, Diffusion, Ceramics and Glasses, and New Materials. Other conceptual decks are planned for the two remaining years of the project. The free university based Apple Software Development Kit (SDK) licensing has been a bit challenging as the university contract officers must sign-off on the agreement each time as Apple updates its software and licensing agreements. And, development devices must be re-provisioned often.

Additionally, anyone who has taught materials engineering courses know how important it is for the students to understand the order of magnitude ranges of material properties for classes of materials and have ready access to materials properties of real engineering materials. While there are resources on the web (such as Matweb.com), the students are conceptually overwhelmed by the huge number of materials and inconsistent sets of materials properties for different materials, especially among materials classes. Texts offer lists of more conceptually contained engineering materials, and the properties must be typed into spreadsheets for any comparisons. Educational and commercial software is available which contains a robust selection of materials and properties from Granta Design, but they do not yet have a touch platform and their products are not free to educational institutions.

The goal here is to have conceptually contained materials sets from which the students can select any number of materials (six at a time on the small iPod screen) so that they can compare one material property (graphically in bar charts or in a list) or plot one material property against another property. For example, the student collaborative groups can be asked to explore comparisons elastic constants from different classifications of materials or different materials for the same application. Or they can explore the stiffness of different types of materials and classifications or for different engineering applications. The students are shown both a visual display and lists (targeting different learning styles). The data for this application, as with the others, is drawn from a server, so the material lists are easy to customize.

Currently, eight material properties are available: Elastic Constant, Density, Yield Strength, Tensile Strength, Poisson's Ratio, Percent Elongation, Linear Coefficient of Thermal Expansion, many others currently in development. Average values are used currently in the application. Current materials in the data set are: steels (8), cast irons (2), stainless steels (6), aluminums (5), coppers (3), titanium (1), nickels (4), magnesiums (2), special/precious alloys (5), thermoplastics and thermosets (15), ceramics/glasses (6), and composites (6), for a current total of 63 with more added as properties are documented. Currently, 110 conceptually grouped materials to choose from are planned. The visual students should display the information graphically while active learners will want to "try it out" by choosing different materials to compare or to see how plotting one material property versus another will change the way they examine the data. Verbal learners will be able to describe the results of their explorations. Reflective learners will benefit from the self-quizzes that accompany the active exercises so that they reflect upon why results show the relationships they do. Lists of data and logical conceptual paths to solutions will be available to help sequential learners. Global learners are assisted by the visual displays, concept questions, audio files, and the links to outside sources. Currently, the apps are being deployed for the first time, while the modules and in-class quizzes are being deployed for the second time. Student feedback for the modules and exam outcomes for the initial deployment of the modules and in-class quizzes are very encouraging.

The next phase of the project will be to also add a toolkit for the collaborative groups. Each collaborative group is to have a toolkit of supporting materials and tools. For example, the student groups could be supported by a conversion tool to help them move between different units and sets of units, mer details, crystal structure support, planes and direction tutor, a mer weight calculator, stress strain diagrams for viscoeleastic materials, a lever rule tutor, fiber reinforced composite ideal properties calculator, and other similar resources. Results from the first deployment of the others apps will help determine which of these are the most vital. Also, we have chosen other apps from the Apple App store to currently support the students: Measures ($0.99), Unit Converter Calculator ($0.99), and MultiConvert [free) (robust and relevant unit conversions], 2D Geometry Formulas ($4.99) [includes hexagons], and Geometry Volumes and Areas ($0.99) [support for crystal structure geometry], TheBarGraph ($0.99) [a bar graphing app to compare material properties which students can email the graph], Algebra Solver ($0.99) and TutorVideo: Trigonometry ($2.99) [basic support for basic mathematics – algebra and trigonometry], Wolfram Alpha ($1.99) [a robust knowledge and data mining tool], and Science VL (free) [a comprehensive science glossary]. Materials related apps include: Materials Unit Weight Database (free), Material Properties ($0.99), and Material Database and Element List ($4.99), although none of these materials related apps are ideal for a basic materials engineering course. Wolfram has recently released applications that support for both algebra and calculus.

Assessment

Every innovation in engineering education needs to be carefully evaluated and assessed to see if the innovations do indeed lead to the intended outcomes [42-52]. The reasons for creating the iCollaborate MSE modules, quizzes and applications are fundamentally three-fold from the students' perspective: improvement in specific learning outcomes, enhanced interest and motivation, and enriched collaborative learning opportunities [53-59]. From an engineering education research perspective, this research will help us better understand why students are having difficulties in the course because we will better understand student misperceptions which also enhances our abilities to provide meaningful concept based experiences within collaborations, improve our ability to focus on troublesome student outcomes and provide additional scaffolding opportunities, and enhance inclusiveness in the classroom.

The assessment plan includes both formative and summative components and will include analyses by gender and ethnicity [60-65]. The Felder-Silverman Index of Learning Styles (ILS) is used to determine the learning styles of individual students. We will also evaluate how students with different learning styles interact with the applications and compare that data to the evaluation data from the collaborative groups. Data is collected by gender and ethnicity. We use the Felder-Oakley team evaluation tools [60] to help us evaluate the effectiveness and the interactions within the collaborative groups. Additionally, formative and summative information is sought from the groups themselves.

"Formative assessment identifies what is working and what needs to be improved while the course is still in progress" [42]. Of course, one of the best ways to find out what is working and what is not working from the student perspective is to ask them. Volunteers including students from traditionally underrepresented groups from the class form a focus group so that we can informally discuss with the students their perceptions about the effectiveness of the modules and the applications. We ask the focus groups to provide specific suggestions for improvement for each module and application. Necessary adjustments will be made to the modules and applications as needed. The effectiveness of the self-quizzing will be compared to the in-class quizzes. We speculate that the all three of the major components of the project are necessary to improve student outcomes, modules, in-class minor stakes quizzing, and self-quizzing with ICT support. The five point Likert scale is used in these formative assessments. Since our apps are in their first quarter of deployment, no assessment data is available yet.

Since the course is the basic engineering component of an interdisciplinary materials science minor, a basic course for engineering technology majors and manufacturing and supply chain management students, we will also exam how pre-existing knowledge and misconceptions affect the student outcomes for the different student populations.

The applications and modules will be revised based upon the initial results and evaluated again within the courses the following year. The applications and modules will be reevaluated and revised again the final summer and adapted for outside and outreach users (high school and middle school students).

Targeted Learning Objectives

Specific student learning objectives are targeted in iCollaborate MSE. "One approach to improving student learning is outcome assessment—the process of providing credible evidence that an instructor's objectives have been obtained. Outcome assessment enables faculty to determine what students know and can do as a result of instruction in a course module, an entire course, or a sequence of courses. This information can be used to indicate to students how successfully they have mastered the course content they are expected to assimilate" [42].

The course objectives have been conceptually grouped. Primary trait analysis (PTA) is used on exam/finals questions to help identify precise conceptual problems and misperceptions. A number of studies have demonstrated the effectiveness of using PTA for these purposes. "Primary trait analysis is a technique whereby faculty members consider an assignment or test and decide what traits or characteristics of student performance are most important in the exercise" [44]. Student Learning Objective Areas (SLOA) for the course are:

Fundamental Characteristics of Materials – SLOA1

1. Conceptually explain the basic and advanced classification schemes that are used to categorize engineering materials;
2. Explain why certain material properties such as the elastic constant (stiffness), the melting temperature, or thermal expansion coefficient is determined by interatomic bonding in solids;
3. Characterize primary and secondary bonds;
4. List the characteristic descriptors for crystal structures and systems;
5. Explain the functions for both the matrix phase and the fiber phases in fiber-reinforced composites.

Crystallography and Structures of Materials – SLOA2

6. Calculate theoretical densities, atomic packing factors, unit cell volumes (SC, BCC, FCC), and planar densities from fundamentals;
7. Explain how different atomic packing sequences affect the mechanical properties of materials;
8. Describe the in-service considerations of using allotropic solids in design;
9. Use the iron-carbon phase diagram and micrographs to describe and identify the many types of steels and cast irons;
10. Understand the terminology used to describe the microstructures of steel;
11. Be able to articulate and use numerical designations for steels, titanium, aluminum and other metals and alloys for engineering applications;
12. Describe the basic classifications of composite materials;

Behaviors of Different Materials – Mechanical – SLOA3

13. Explain the differences in mechanical properties for isotropic and anisotropic materials;
14. Explain the differences in mechanical materials properties for single crystalline, polycrystalline, semi-crystalline and amorphous materials;
15. Describe how and why defects (point, line and interfacial) in materials greatly affect engineering properties and limit their uses in practice;
16. Evaluate the effect of size and distribution of molecular weights on the basic mechanical materials properties of polymers;
17. Explain why the percent of crystallinity affects the mechanical properties of thermoplastic materials;
18. Describe basic concepts of deformation mechanisms (dislocations, slip, fracture);
19. Explain strengthening mechanisms for mechanical properties;

Polymers – SLOA4

20. Describe the basic structure of and properties for engineering polymers;
21. Identify key differences in the properties of and applications for thermoplastics, elastomers, and thermosetting plastics;
22. Draw the repeat units for PE, PVC, PTFE, PP, PS;
23. Describe the four types of molecular structures in polymers (linear, branched, crosslinked, and networked);
24. Calculate the number and weight average molecular weights and degree of polymerization for simple polymers;
25. Describe the fabrication methods for commodity plastics (injection molding, blow molding, thermoforming, extrusion);
26. Describe the glass transition temperature of polymers;

Application of Mechanical Properties – SLOA5

27. Describe why each of the fundamental mechanical engineering properties of materials covered in the course (stress, strain, elastic constant, creep, fatigue, wear, hardness, Poisson's ratio, toughness, ductility, flexural strength, impact strength, elongation) are important in engineering design;
28. Distinguish between geometric and materials properties effects in engineering designs;
29. Be able to calculate engineering stress, strain and the elastic constant from data and for basic engineering applications;
30. Select the appropriate engineering materials for specific engineering applications using: yield strength, tensile strength (or flexural strength), ductility or elongation, hardness, fatigue life, endurance limit, and creep;
31. Size basic parts for simple engineering designs using safety factors;
32. Estimate the elastic constants of a fiber-polymer composite given the volume fractions of each material;

In Service Considerations – SLOA6

33. Describe the fundamentals of how engineering materials fracture or fail (and the usual causes of failure);
34. Evaluate the effect of the in-service operating environment on the estimated life-time of materials or fit for use;
35. Evaluate the life cycle of engineering materials in service.

Overall

Important goals of this project are to improve student learning outcomes in MSE, improve retention rates, successful completion rates, self-confidence, attitudes, and enjoyment of basic MSE courses for all students, but especially for women and other traditionally underrepresented groups. Careful and detailed assessments are underway to measure improvements in targeted learning objectives for the course, increases in student successful completion of the course, increases in student retention in the course, and improvements in student engagement. Careful assessments will determine if the iCollaborate MSE methodology improves conceptual understanding of the fundamentals of MSE education and improves higher order cognitive skills, especially in connecting design criteria and geometry features to materials and the material properties. Finally, improvements in the ability of the students to complete open-ended design problems is also evaluated as part of iCollaborate.

For this project, the student collaborative group size is either two or three. The devices are handed-out to the groups during each 2-hour class period and collected at the end of each class. Collaborative groups can check out their device long-term (about half do) and individuals can check out other devices if additional work is needed on specific tasks. Individuals can check out a device, but group interactions will be emphasized and encouraged. Group study sessions will be held the evening before exams and the student groups are not allowed access to the devices during those periods or the exams.

Although the entire point of this project is to create an integrated learning environment that fosters inclusiveness and improves learning outcomes and success for all students, but especially for women and students from other underrepresented groups, we know that providing additional opportunities for outreach in materials engineering education is also important. The applications will be placed on the Apple Applications store for free as soon as they are robust enough to do so. If our project is successful and has the intended outcomes, it is intended that the applications be adapted for use in high school outreach and one is targeted for middle school students. We are especially eager to see if our approach has measurable outcomes to foster a more diverse climate in undergraduate education in engineering technology. Near the end of the project, we will seek to demonstrate the applications at national conferences. At the end of the project, the all applications and modules will placed on the NSDL repository.

Conclusions

The overall objectives of the research proposed in iCollaborate MSE project are to determine if improvements in student learning outcomes, engagement, and successful completion and retention 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 Information Communication Technology (ICT) enabled inductive teaching and learning environment. The combination of specific learning objective targets within modules, completed in collaborative groups, which are supported by conceptually contained data, visuals, audio, and information from the iPod Touch, and in-class quizzes will hopefully lead to improvements in student learning, engagement and retention. All of the concepts that are to be tested have foundations in STEM education research. While the iPod Touch is the ICT device used because of its multi-touch and wireless multi-functional features, the applications software can be translated to other smart devices.

The MSE education applications for this project will be freely disseminated through the Apple Applications store after they are tested and robust enough to do so. Currently, the apps are in their first quarter of deployment, while the modules and the in-class quizzing components are in their second quarter of deployment. The application modules are divided into basic pre-requisite knowledge (BasicK), Vocabulary (Vocab), basic MSE knowledge to be acquired during the course (Tune-Up), and conceptual learning (ConQuest). Sixty-three materials and eight properties in list form and in graphical displays are currently deployed with more added as sound data is documented. Since the applications draw data sets from servers, the apps are designed to be easily customizable. No assessment data is available yet since the apps are in their first quarter of deployment.

While much is known about more effective practices in engineering education, many barriers exist to implementing them within individual courses, especially in institutions with limited resources. It is hoped that the work completed in this project will remove some of those barriers for the many faculty across the world teaching basic materials engineering courses. But most of all, it is hoped that the research completed will enable many more students to be successful and contribute their much needed talents toward a more diverse engineering culture.

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