CCLI Type 1: Enhancing the ECE101 Curriculum Through Student Diversity

Objectives. ECE 101: *Exploring Digital Information Technology* strives to prepare students for a meaningful role in an increasingly technological society. Unfortunately, many students fail to see underlying connections between course content and their own personal interests. The goals of this project are to 1) better engage the students in the course topics, 2) quickly integrate diverse student-driven subject matter back into the course, and 3) empower the students to more effectively apply new skills to their lives and careers. When students recognize the impact of their own ideas on the course direction and see the immediate application to their own interests, the "Diversity Harnessing" cycle (see Figure 1) feeds upon itself and presents a driving force in their education.

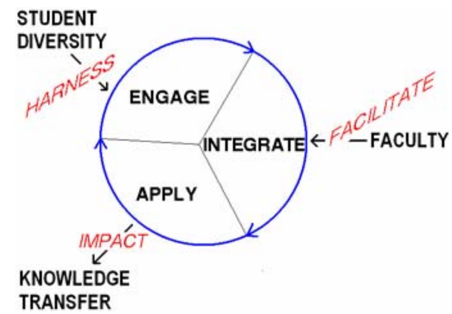


Figure 1. Diversity Harnessing

Methods. To enable Diversity Harnessing for broad adoption, there is a need to outline the teaching pedagogy, provide the course structure (information technology and materials) and simplify the instruction overhead (to allow more instructor focus on integration). Cooperative learning methods will be utilized in and out of the classroom to build community. A structure for effective teamwork and evaluation will be implemented. Course notes and homework will be restructured to optimize time-on-task with student-instructor dialogue in the lecture, to provide prerequisite training to those who need it, and to provide space for engaging student-generated subject matter. Warm-up, in-class, and topic-transition materials will be prepared. The day before the lecture, students will read selected course note "modules" and then answer a few questions regarding the material plus one or two extending beyond. The answers to the latter questions provide student-driven material that can be folded back into case studies in the next lecture or homework at the instructor's discretion. The last five minutes of lecture will allow students to again answer a few questions about the material. Their unbiased answers will serve to transition the students towards thinking into the next topic. Success of the course re-design will be assessed through a longitudinal study with interviews conducted over the duration of the grant.

Intellectual Merit. In this project, we will apply proven techniques from cooperative learning in an unusual engineering course for students outside engineering. Using these techniques, we will transform the course to harvest the diversity of students and to incorporate course content of immediate interest to students. We expect to demonstrate that these innovative methods for harnessing diversity will enable students to apply new skills in their everyday lives and careers. Using both standard questionnaires and student interviews, will carefully assess how the modified course promotes student learning. The PIs have the experience and background to implement the course changes and to assess their effectiveness.

Broader Impacts. We expect that the new methods for harnessing student diversity will improve student engagement, and they will be transferable to other introductory STEM courses. Because the specific ECE 101 course materials are presented on a generic information technology platform and require little expense in hardware beyond a desktop computer with a sound card, we also expect that the course itself could be replicated at other institutions. Undergraduate and graduate student researchers will participate in the development of course materials and in the assessment of their effectiveness.

CCLI Type 1: Enhancing the ECE101 Curriculum Through Student Diversity

1. Motivation

1.1 Challenges in STEM Teaching

In recent years, colleges and universities have sought to strengthen instruction in science, technology, engineering, and mathematics (STEM) for students not majoring in STEM fields. Many courses have appeared to begin to fill this need. But how does such a course manage to go beyond “stirring the dust of knowledge” and actually develop skills that students can integrate into their lives? Current state-of-the-art in teaching recognizes the need for student engagement. If the students do not take personal interest in the material, they are not likely to achieve even basic “remembering” skills, let alone higher skills such as “understanding” and “applying” (Krathwohl, 2002). Worse yet, if the students are not exposed to applications much beyond the standard course examples, they are not even likely to remember the information much beyond the semester’s end.

State-of-the-art tools for student engagement are well-established and discussed in Section 3. With some restructuring of a course and its objectives, student engagement can be brought to high levels while simultaneously improving student motivation. The material can also be made more interesting by applying it directly to applications that the students can appreciate. After teaching engineering to non-science majors for 6 years, Kuc (2001) observed “…each lecture [needs to provide] a concept that students find interesting enough to discuss with fellow students in the dining hall.” Orr and Cyganski (1988) found after a first offering of a course in engineering that the students found too little relevance to their own majors and too much bias towards engineering applications. After some work to include “an abundance of important and academically valid material,” they found it “difficult to keep the course cohesive.” Games and puzzles have long been recognized as generic, interesting applications that cross discipline boundaries (e.g., Cook, 1977; Hill, Ray, Blair, & Carver, 2003). However, unless the students intend to apply their skill set for gaming purposes, they may perceive these tasks as lacking value (Layman, Williams, & Slaten, 2007). To gain the skill necessary to transfer their knowledge, students should learn in a “domain that is relevant” to their interests and to their personal lives (Guzdial & Forte, 2005; Krupczak, 1997). Some instructors choose topics and applications in the classroom more applicable to student interests by conducting an interest survey during course design and tailoring the course to those results (e.g., Krupczak et al., 2005). Two problems might be encountered with this technique: even a large student survey will not provide the best set of materials to match the interests of a small sample of students especially for smaller class sizes. Further, a course in say, technology, will likely outlive the appropriateness of the chosen applications. A course too deeply dependent on a set of applications would require substantial redesign in scope every few years and might quickly overburden the staff and eventually degrade in quality and consistency.

This proposal suggests a new direction for instructional design in introductory STEM courses. The course topics remain fixed but not too tightly coupled to current trends and standards. Instead, examples, applications, and even homework and exam problems are adaptively provided by students to enhance the selection made by the instructor. Diversity within the student population will provide a diverse set of materials while remaining specifically relevant to the interests of the current students. The success of the plan depends critically on being able to provide the proper instructional design such that effort does not have to focus directly on engagement techniques, but rather on regular integration of the student-driven content back into the course.

1.2 Why ECE 101?

To prepare students for a meaningful role in an increasingly technological society, we offer a course ECE 101, *Exploring Digital Information Technology,* for students outside the College of Engineering at the University of Illinois at Urbana-Champaign. ECE 101 carries three semester hours of credit and satisfies the campus's general education requirement in natural sciences and technology. The course helps students understand scientific and quantitative principles that underlie the operation of selected information technologies and, just as important, the engineering processes by which technologies are created. Each week, ECE 101students attend two hours of lecture by a faculty instructor and two hours of laboratory/ discussion led by a graduate teaching assistant. Each semester, the course enrolls forty to sixty students. Most students are freshman and sophomores. About half are enrolled in majors outside the sciences.

In ECE 101, students investigate the principles and processes for the development of information technologies such as Web design, digital music, digital images, digital logic, state machines, data compression, error correction, information security, and communication networks. They are also required to apply the engineering design process to complete a project to build a device for an application of their choice. In the weekly laboratory exercises, students make realistic and meaningful design choices while applying both technical principles and creativity. Specifically, students learn that:

- Technological products are not magic: they rely on physical and mathematical principles.
- Development of new products requires scientific knowledge and intellectual creativity.
- New products are not created out of a vacuum: they are built logically on experience gained with previous designs; many technological features merge to form a larger system.
- Engineering design decisions involve tradeoffs between cost and performance to achieve technical goals within economic and social constraints.
- Technologies are shaped by society and, in turn, technologies have an impact on society.

ECE 101 is not a high-level how-stuff-works course. Instead, it provides students with the minimal engineering skills to pursue their own investigations and draw their own conclusions. In this way, the topics are already significantly decoupled from the examples. For example, during the semester students learn concepts about analog signals, how analog signals are sampled and quantized in a sufficient manner to preserve important information, how digital signals acquired in this manner contain redundancy, how the redundancy can be systematically removed using a carefully drafted set of rules, and how limits exist on how far a set of rules can go before the data becomes inaccurate. Specific compression schemes such as run-length encoding or JPEG may serve as good case studies during this period, and upon completion of the course, the students are prepared to understand data compression in any other setting. They hold the tools necessary to not only remember how one technology scheme works, but also to ask the right questions and seek the right data to discover how any other scheme works.

The decoupled nature of applications from core topics allows ECE 101 to pursue applications driven by student diversity. Suppose, for example, that a broadly-posed question regarding the topic of "summaries" leads a student to think of the statements made by a judge when delivering a sentence. This somewhat innocuous observation can be made into a key case study in compression and tie in several other aspects of digital information theory as well. The instructor could facilitate the class dialogue by asking such questions as: "Can anyone suggest a case that has been in the news?" (Students become interested.) "Which laws and rulings might carry the most weight in this ruling?" (Students discuss how different information carries different weight.) "At what point can the research be considered finished and the judge be confident that the ruling is fair?" (Compression results in some loss of information, but is it noticeable?) "Could the results of previous laws and rulings be conceivably tabulated in a database (in the future) and the judge replaced by a computer?" (Information becomes bits; computers can be told how to operate on bits. Does intuition play a role?) Therefore, each question can allow the students to explore the relationship between compression and the concise representation of data … eventually leading the student toward a potential application of digital information technology in a new setting. We expect that this style of teaching will enable students to broaden their view of digital information technology and prepare them for an ever-changing world.

We believe that carefully constructed notes combined with properly-worded questions can elicit a host of observations and problems. These observations and problems continually form the basis of case studies in the lecture, homework assignments, and even exam problems. Problems generated by the students are likely to be directly related to their disciplines and interests. The data can be stored in a database and shared across institutions, thus providing a wealth of application options crossing many different disciplines.

2. Research Objectives

2.1 New Pedagogy for Diversity Harnessing

The teaching pedagogy proposed is designed to empower students to recognize their individual strengths and provide valuable contributions to the class. By incorporating cooperative learning and other proven teaching methods into ECE 101 and applying them in new ways, we aim to achieve three goals: better student engagement in learning, integration of students' experiences directly into the course material (broadening their view of the digital information world), and empowering students to apply skills obtained from ECE 101 to their lives and careers in diverse applications, Students would become better consumers, designers and/or researchers. The culmination of these goals, termed **Diversity Harnessing**, is enabled by providing students with the confidence necessary to freely contribute personal observations to the rest of the class. Towards this result, three key pedagogical principles are needed: 1) community, 2) collaborations, and 3) accountability. These three "Cs" form a solid base for a course focused on Diversity Harnessing.

Achieving a sense of **community** will be initiated through time devoted in the classroom to get to know the students personally. The idea is to develop a framework for creating a learning community among the students and the staff. A wiki will provide a location for students (and staff) to define themselves, form study groups, and collaborate for the course project. Regular team study sessions will be scheduled outside the classroom, further developing the sense of community.

With community established, **collaboration** becomes easier between students and between students and staff. Here, we must develop a technological and social framework that facilitates collaboration among the staff and students. Often, this is difficult to achieve in any class. Many students avoid participating in class sessions because they are shy or because they fear of showing ignorance. Cooperative learning techniques can still fall short of uniting all of the class in active participation. The proposed technique of Diversity Harnessing hopes to look beyond the classroom in instilling confidence and in motivating even the most reluctant students to contribute (at least in anonymity) and achieve some level of productive engagement of 100% of the students.

Accountability motivates action. Collaborative action is the only means to attain 100% productive engagement of the students. We wish to develop a system of accountability that provides the stimulus to drive the goals of community and cooperation. The students should understand their duties and be held accountable for their completion. Students are known to respond positively when more is expected of them by staff and peers, and accountability for students implies to holding them to a high standard in all aspects of their course participation.

Accountability is not just for kids. While providing the students with the proper tools and motivation would hopefully result in lively class participation, students are unlikely to buy into the concept without seeing a cost for not doing so. The course staff is then accountable for adequately explaining this cost structure and holding the students to it. Accountability exists in the staff's requirement for due diligence in providing swift feedback demonstrating the usefulness of student contributions is critical as it is this feedback that serves as fuel for more collaboration. Accountability for staff also motivates regular gauging of the effectiveness of the diversity-harnessing schemes. This shows the student body that the staff is committed to the task of harnessing diversity and sets the bar for regular interaction.

2.2 Assessment and Evaluation Plan

By incorporating cooperative learning methods into ECE 101, we aim to achieve three goals: better student engagement in learning, integration of students' experiences into the course, and empowering students to apply skill sets obtained from ECE 101 to their lives and careers. We will collect baseline data from the old version of ECE 101 in 2009–2010 and additional data from the new version of ECE 101 in 2010–2011. We will be able to compare the experiences of students in ECE 101 before and after the incorporation of cooperative learning methods.

For the first goal, student engagement, we will use the Student Engagement Course Questionnaire, SECQ (Handelsman, Briggs, Sullivan, & Towler, 1998). Unlike the famous National Survey of Student Engagement, the SECQ is designed to measure student engagement during a single course. The SECQ is a reliable measure of student engagement along four internally consistent factors: skills, emotion, participation, and performance. After we pilot-test the SECQ in the fall of 2009, we will obtain baseline data in the spring of 2010 by administering the SECQ in ECE 101 at several times of the semester. We will then administer the SECQ to collect student engagement data for the new version of ECE 101 in the 2010–2011 academic year.

For the second goal, we will simply collect students' diverse ideas during offerings of ECE 101 in the baseline year, 2009–10, and during the offerings of the new version of ECE 101 in 2010–2011. We will analyze the number and quality of the students' ideas "blindly," with the names of students and the date of collection removed.

For the third goal, application of skill sets, we will interview students before and after they take ECE 101. For the baseline assessment, in the fall of 2009 and spring of 2010, we will conduct cross-sectional 30-minute individual interviews of twenty students who previously completed ECE 101 one, two, three, and four semesters ago. The interview protocol will prompt students to reflect on how topics from their general education courses—particularly in ECE 101—relate to their current courses or their other recent experiences (Suskie, 2004, chapter 9). Then we will interview a random selection of a total of twenty students in the new version of ECE 101 at the beginning of the fall 2010 and spring 2011 semesters. We will follow these twenty students longitudinally, interviewing them individually each semester for the duration of the project.

We will conduct a qualitative analysis of the interview data (Miles & Huberman, 1994). Because there appears to be no accepted model of how students use knowledge from general education courses in science and engineering, we will take a standard grounded theory approach (Strauss & Corbin, 1998): after individual members of our research team code the interview data independently, we will construct themes that describe how students apply ideas from ECE 101 across time. We will compare the responses of the two populations: students who took the previous version of ECE 101, and students who took the new version of ECE 101.

Before we conduct the assessments, we will secure approval from the University of Illinois's Institutional Review Board for research with human subjects. We expect that our project would be exempt from full IRB review under federal regulation 46.101(b)(1) for research in established educational settings. The risks will be minimal: only the potential breach of confidentiality. We will obtain informed consent from each interviewed student.

2.3 Intellectual Merit

In this project, we will apply proven techniques from cooperative learning in an unusual engineering course for students outside engineering. Using these techniques, we will transform the course to harvest the diversity of students and to incorporate course content of immediate interest to students. We expect to demonstrate that these innovative methods for harnessing diversity will improve student engagement and enable students to apply new skills in their everyday lives and careers. Using both standard questionnaires and student interviews, will carefully assess how the modified course promotes student learning. The PIs have the experience and background to implement the course changes and to assess their effectiveness.

PI Michael C. Loui is Professor of Electrical and Computer Engineering and University Distinguished Teacher/Scholar at the University of Illinois at Urbana-Champaign. Since 2006, he has served as executive editor of *College Teaching*, one of the oldest interdisciplinary scholarly journals on college teaching. He collaborates with undergraduate and graduate students in engineering education research projects. He is experienced in both quantitative and qualitiative research methods, including grounded theory (e.g., Herman, Kaczmarczyk, Loui, & Zilles, 2009). His current NSF-funded projects include the creation of concept inventories for three fundamental subjects in computer science (NSF Grant DUE-0618589), and the development and assessment of role-play scenarios for teaching responsible conduct of research (NSF Grant EEC-0628814). In 1995, Professor Loui won the campus's Luckman Award for Distinguished Undergraduate Teaching. In 2003, he was named a Carnegie Scholar by the Carnegie Foundation for the Advancement of Teaching. In 2006, he was elected Fellow of the IEEE for leadership in teaching engineering ethics. Professor Loui and Senior Investigator Jones created the ECE 101 course in Spring 2003. For this project, he will take responsibility for the assessment and evaluation activities, including the direct supervision of the graduate research assistant.

Results from Prior Relevant NSF Support

NSF Grant SES-0138309: *National Institute for Engineering Ethics Video Project: A Sequel to Gilbane Gold*. PIs: J. H. Smith, W. D. Lawson, M. C. Loui, S. P. Nichols, P. E. Ulmer, V. Weil. $265,000 from NSF and $80,000 from private contributions, 2002 to 2005.

We developed a new instructional video *Incident at Morales*, which dramatizes a fictional but realistic case study in engineering ethics. The video emphasizes common ethical issues in engineering practice, and it shows engineering in an international context. We sent free copies of the video and study guide to the deans of all engineering schools in the United States. We showed the video at several conferences, including a meeting at the National Academy of Engineering in 2003. We demonstrated the pedagogical use of the video with two cooperative learning techniques in a special session at the Frontiers in Education Conference (Loui, et al. 2003). We assessed the educational effectiveness of the video with both student and professional audiences (Loui, 2006). Other publications supported by this grant: (Hashemian & Loui, 2005), (Loui, 2005a), (Loui, 2005b).

Co-PI Christopher D. Schmitz is a Lecturer in Electrical and Computer Engineering and a Research Specialist at the Beckman Institute at the University of Illinois at Urbana-Champaign. An expert in wireless communication and signal processing, he has been active in teaching at the college level since 1993. In 2004, he was assigned by the ECE department to redevelop a laboratory course in digital communications. In 2005, he was asked to take a lead role in teaching ECE 101. He quickly enhanced the use of 21st century technology in the classroom to enhance the student experience. In 2006, he was invited to National Instrument's Worldwide Graphical System Design Conference to present the use of LabVIEW graphical programming language for teaching undergraduates and, in 2007, was invited back to present on the use of LabVIEW and the NI-PXI in supporting undergraduate projects in communications. For this project, he will be responsible for the instructional design, information technology tools used to facilitate Diversity Harnessing, material development and dissemination of the materials.

Senior Investigator Douglas L. Jones is Professor of Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign. He served on the IEEE Signal Processing Society's Board of Governers from 2002-2004. He have developed many widely-used open source signal processing texts (available at http://cnx.org) and was Connexions Author of the Year in 2003 and received the ECE Ronald W. Pratt Faculty Outstanding Teaching Award in 2006. Professor Jones and PI Michael Loui created the ECE 101 course in Spring 2003. For this project, he will hold regular weekly discussions with co-PI Christopher Schmitz to offer his expertise in undergraduate teaching regarding the pedagogy, structure and content of the course as well as educational modules for web-based dissemination of course material.

2.4 Broader Impact

2.4.1 Diversity

This pilot study will provide the structure for using technology to regularly and effectively increase student participation and provide diversity-driven contribution to course content. We expect that the new methods for harnessing student diversity will improve student engagement, and they will be transferable to other introductory STEM courses. The engagement of minorities or underrepresented students will be enhanced through this method. Students will recognize the value of diversity in extending course material across disciplines. Instructors will recognize the value of diversity in providing all students a deeper understanding of the course material.

2.4.2 Transferability

Because the specific ECE 101 course materials are presented on a generic information technology platform and require little expense in hardware beyond a desktop computer with a sound card (less than $100 per computer), we expect that the course itself could be replicated at other institutions.

2.4.3 Mentoring

The project provides work and mentoring for both a graduate research assistant and an undergraduate. The research assistant will be mentored in the arts of student and course assessment under the guidance of PI Michael Loui. The undergraduate will assist in testing of materials prior to distribution in the course and will help assemble assessment data as well. The undergraduate will be mentored primarily by co-PI Christopher Schmitz in the areas of 21st century teaching techniques in active and cooperative learning as well as advanced methods in collaboration.

3. State of the Art

The state of the art in teaching is guided by the Seven Principles for Good Practice in Undergraduate Education (Chickering & Gamson, 1991) where good practice is that which:

1. encourages student - faculty contact
2. encourages cooperation among students
3. encourages active learning
4. gives prompt feedback
5. emphasizes time on task
6. communicates high expectations
7. respects diverse talents and ways of learning

The goal of this study is not to demonstrate how to achieve all of these points, but rather, how to harness diversity within ECE 101 while not loosing sight of the end goal of effective teaching of the concepts. Diversity Harnessing requires first and foremost, the active engagement of students in all aspects of the course, in and out of the classroom. Engagement has been closely tied to interaction between the students and interaction with the instructor (Astin, 1993; Smith, Sheppard, Johnson, & Johnson, 2005). How are these interactions facilitated in state of the art teaching? Cooperative or collaborative learning techniques are now widely accepted as some of the most effective teaching tools. Including such tools as think-pair-share, jigsaw, and academic controversies, these techniques have been shown to enhance self esteem, personal satisfaction, positive attitudes toward the teacher, a feeling of inclusion, and mastery of the material while setting high expectations of the student and reducing testing anxiety (Panitz & Panitz).

Team formation is often critical to success in cooperative learning. In fifteen years of chasing the dream, Felder (2001) has compiled many observations regarding successful teamwork. According to Felder formation of heterogeneous teams of as many as four students would be deemed appropriate. Attrition to three students is acceptable, but two-student teams often result in a leader-follower scenario. Johnson, Johnson and Smith (1998) suggest that five criteria be met by the teams

1. positive interdependence
2. individual accountability
3. face-to-face interaction
4. Development of interpersonal skills
5. Regular self-assessment of group functioning

Felder (2001) also recommends mixing and matching according to abilities. The composition of each team should allow for students to find a key role in the task and the opportunity to "teach" their portion to the rest of the group. A mechanism should be in place for self-imposed or group-imposed removal of a member as well as complete dissolving of the group which can then be reassembled with the others.

Just-in-Time Teaching (JiTT) refers to a feedback loop in which answers to questions and student observations and comments are fed into the classroom discussions (Novak, 1984). The student-generated material from JiTT is generally geared towards identifying common misconceptions or incorrect assumptions. Service learning is centered under the concept that homework and case studies "should demonstrate the learning objective of the assignment and be interesting to the student," and also prove to be "meaningful" in life (Layman, Williams, & Slaten, 2007). Lanny Arvan, CIO and Associate Dean for eLearning at the University of Illinois has gone so far as to say we should "… encourage students to become the creators of learning objects …" and thereby formulating their own interests and, in effect, becoming teachers within the course (Arvan, 2004). **Problem-based learning** (PBL) is a "problem comes first" style of teaching. When used within cooperative learning, problem-based learning generally implies that the students are posed a problem and the focus is on problem management less than on the precise solution.

Accountability of students also serves as a valuable motivator. If not held accountable, student's time is likely to be devoted where the student is held most accountable for their work. Felder (2001) suggests that accountability may be maintained through individual testing, peer ratings on the "citizenship" of team members and used to adjust grades through a rubric, and providing for removal of a member from a team. Accountability should be a visible entity relayed by regular and consistent feedback of the metrics gauging student performance including Felder's notion of citizenship. Accountability must also reside with the instructor who must monitor the success of the different aspects of the teaching pedagogy and identify and rectify trouble spots before trouble occurs.

4. Methods

4.1 Pedagogy

Our teaching pedagogy first focuses on a re-balancing of topics to be explored before, during and after each class session. Prior to the session, warm-up materials provided through online resources will introduce basic concepts easily grasped by individual or small group study. We recognize that simply making such material available does not imply that it will be used and without feedback, the effectiveness of the material is never evaluated. To achieve this end, students will be required to answer simply-phrased, but subtle questions about the pre-lecture module. This provides a mapping of their pre-lecture understanding of the upcoming topic. They are asked to anonymously provide their own subject matter based on their hobbies, interests or field of study. This listing is examined by the lecturer for use in advance of the meeting. Students then witness their contributions to the class without fear of personal embarrassment. The instructor should take effort to represent contributions from all students within lectures and homework early in the semester.

The teaching pedagogy secondly focuses on harnessing diversity within the lecture hall or classroom. First, the students become empowered to ask questions by using collaborative methods where student teams answer problems jointly thus reducing anxiety regarding so-called "stupid" answers. Collaborative and active learning techniques are tried and proven in their effectiveness in the classroom. When this level of comfort in the classroom is achieved, discussions arising from the individualism of the course participants will enable students to interpret the value and application of the STEM materials to a much broader world.

Our task is similar to service learning or Arvan's dialogic learning objects (Arvan, 2004), but we go as far to claim that it is the students who should drive not only the direction, but the subject matter used to facilitate the core topics and by creating meaningful assignments, meaningful case studies in lecture, and meaningful laboratory experiments. We find utility in the problem-first aspect of PBL teaching and utilize it to motivate topics or scientific solutions. After all, the problem is often the motivator of innovation in real-life engineering. Felder compares case studies (PBL) to "straight expository learning" (traditional lecture style) and maintains that each can incorporate active/cooperative learning strategies and each has its place. JiTT forms the basis of such pre-lecture materials as the "WarmUp" material used by Jeff Watt (Watt, 2006) and the "Preflight" materials used in introductory physics course at the University of Illinois (Selen, 2002).

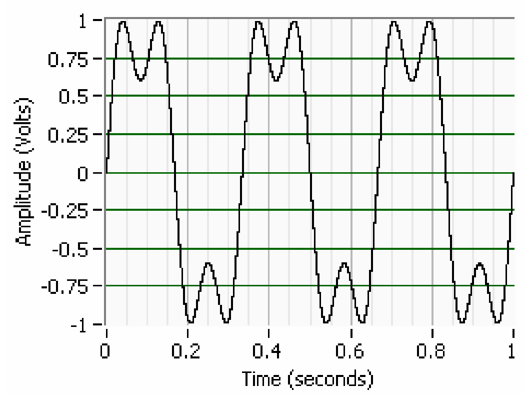
4.2 Course Notes and Lecture Materials

Prior to each class session, the students will complete a (roughly) 30 minute learning module. The module will present a lead-in to the lecture material to be covered the next day. At the completion of the module, the student will be asked several precise, but subtle questions regarding the material. The purpose of the questions is not to test the individual on the material, but rather to 1) gain a perspective on how well the material was understood and 2) gain student-driven ideas for classroom case studies on the topic. The subtlety of the questions is purposeful in that the students are not pre-disposed to a particular answer. Take, for example, the following excerpts from one possible warm-up exercise suitable for ECE 101:

> The student has just been introduced to the concept of analog signals with examples such as voice, light intensity, temperature, etc. All of these have a measureable feature that is both continuous in amplitude as well as continuous in time.
>
> You ask the students to imagine and describe a situation in which two people need to communicate some kind of information over a distance or within a noisy environment. Do people in this situation generally find a method of relaying that information such as the message remains intact? Explain.
>
> Perhaps the answers may include construction workers who resort to hand signals or a child in church who yells over the choir. The answer may be somewhat biased by the examples of analog signals given in the pre-lecture warm up or, perhaps, their expectation to provide an answer in the realm of Digital Information Technology: "I used a cell phone to call my grandmother." Ideally, with some massaging of the question, the results may provide a good case study for the following lecture.

The lecture material is pared down from the course notes, focusing on the core idea. The lecture material should be comparable in length to perhaps 30 minutes worth of a traditional 50 minute lecture. The remaining 20 minutes allows for incorporation of the student-driven subject matter obtained through Diversity Harnessing, Cooperative Learning techniques and team projects, and transition questions. For example, continuing the example above, the lecture may play out as follows:

> In lecture, the student-generated construction worker example is presented. The students reflect on the noisy environment and one worker three stories up trying to relay equipment needs to another worker on the ground. It seems likely that clear hand signals (or cell phones) would be needed. The discussion focuses on the fragility of analog signals … like an Illinois governor, they are easily corrupted. Sending clear signals and leaving out less important details may be more constructive. The students are engaged and intrigued that their pre-lecture observations have become course material. The instructor now moves to a more refined problem: The classroom divides into learning teams (kept intact throughout several weeks). Team A is to send the message 1 to team B (who is provided only an empty graph and no knowledge of message 1):



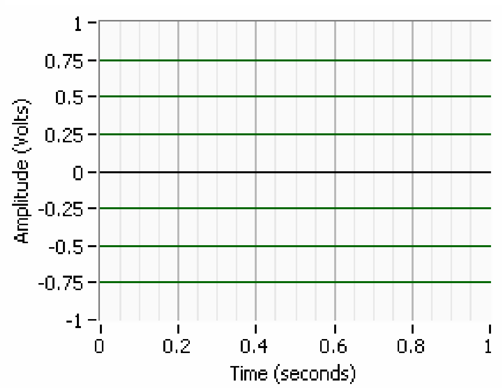


Figure 2. Team A's Message 1.

Figure 3: Team B's empty graph.

Team A is given an opportunity to strategize, then given 30 seconds to relay their information. Most likely, they will focus on extreme points and perhaps the periodicity of the signal. They may not succeed. Now, Team B is asked to send the message 2 back to Team A.

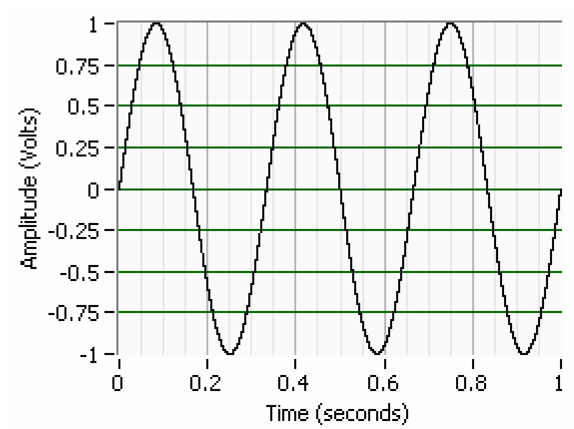


Figure 4: Team B's message 2.

Again, team B is given an opportunity to strategize and then to relay information. Team B may follow the example set by team A. They will likely succeed. The teacher now directs the dialogue towards the Shannon-Nyquist Sampling Theorem $f_s \geq 2f_{max}$ which can now be introduced as a method by which Team A ultimately discovered by trying to efficiently relay the first message. In essence, only a few regularly spaced samples determined by f_{max} are needed with the rule that these sample points should be "smoothly" reconnected. Team B will have reinforced that theory by achieving their goal due to a smaller f_{max}. After examining the core topic with a overly-simplified example, the instructor may return to the topic of construction workers. How does a cell phone system solve the problem? How is the same information conveyed? Does the Sampling Theorem apply?

With the core material successfully covered in lecture and the students having learned it with both traditional material provided by the lecturer as well as content furnished by the students, the lecture can conclude with a the opportunity for students to summarize what they have learned and begin a transition to the next topic. The transition may go something like:

> The instructor has the students note that the first message is actually the two sinusoids described by the summation of amplitude, frequency and phase triplets, (A,f,θ), given by (1,3,0) plus (0.4,9,0) and therefore f_{max}= 9 Hz. Message 2 is a single sinusoid given by (1,3,0). In a format similar to the one-minute paper (Angelo & Cross, 1993), ask the students:
>
> Which message appears to hold more "information?
>
> Why is information often summarized before sharing? Give an example of where you have seen this.
>
> What do you think it means to compress (or zip) something on your computer?
>
> The instructor may also have the students rate each team member on their performance during today's exercise: no show, weak, satisfactory, good, or awesome! They may also rate the content and/or presentation of the lecture material.

The transitional material has then prepared the students for the next topic, data compression in this case, and may even provide some additional student-generated subject matter for course content consideration.

A natural question to ask would be, "What happens to the other 20 minutes of material not covered in lecture?" Well, the short answer is that it was replaced with a deeper understanding of the 30 minutes that was presented. You might also argue that the material removed is still present in the course notes and the students are held accountable for it through the assignments. In reality, we might expect that this material, if not easily absorbed after building a solid understanding of the core, may have been the first items to escape memory at semester's end.

4.3 Assignments

The assignment materials to be developed are triple-layered. The middle layer defines the level at which the students are required to perform. The lowest layer provides catch-up materials for students who feel particularly behind on the course prerequisites. The upper layer provides challenges beyond the standard course material and encourages the students to apply, analyze, evaluate, and create by utilization of their newfound skills. Week by week, the students are invited to complete a subset of problems from the three homework layers. While the second layer constitutes a required set, there is no penalty for selecting lowest layer problems over the highest layer problems. In fact, these two layers are not differentiated in the assignment, but are rather thrown together into one "grab bag" of problems. It is anticipated that the students who find the lowest-layer materials to be rather tedious or mundane will opt for the physically shorter, but more challenging highest-layer materials. The students will be encouraged to work on assignments in teams, jointly presenting solutions to required problems, but taking accountability for specific problem solutions from the grab bag. No two team members may assume accountability for the same grab bag problem. Grab bag problems should consist of student-generated questions from past and present, selected and maintained by the instructor.

5. Research Tasks and Execution Plan

Year 1

Fall semester 2009: Conduct pilot test of SECQ, cross-sectional study of past students.

Spring Semester 2010: Collect baseline SECQ data at several times throughout, continue cross-sectional study.

Summer 2010: Map course notes into warm-up, lecture core, and transitional material. Construct tiered homework, separating core content from prerequisite and adding student-generated problems as possible. Choose educational technologies for community-building framework for handling student direction and facilitating teamwork.

Year 2

Fall Semester 2010: Begin teaching course under diversity-harnessing structure. Administer SECQ. Begin longitudinal interviews. Presentation at ASEE/IEEE Frontiers in Education Conference in October.

Spring Semester 2011: Continue longitudinal interviews. Administer SECQ Presentation at ACM SIGCSE Symposium on Computer Science Education in March.

Summer 2011: Complete analysis of current data. Begin dissemination of materials at cnx.org and enable IT resource for across-institution collaboration for instructors.

Year 3

Fall Semester 2011: Continue longitudinal study. Presentation at ASEE/IEEE Frontiers in Education Conference in October.

Spring Semester 2012: Complete longitudinal study. Present results at ACM SIGCSE Symposium on Computer Science Education in March.

Summer 2012: Complete analysis of current data. Complete dissemination of materials at cnx.org.

6. Integrating Research, Education, and Diversity into the Project

This project proposes invoking student engagement in a novel way using proven tools coupled with the new idea of Diversity Harnessing. If proven effective, such a tool is likely to be accepted and encouraged by the teaching and learning community.

This project will also utilize a research assistant to help in the student surveys and assess the results. An undergraduate student will help prepare and/or test materials designed specifically for Diversity Harnessing.

By its very nature, this technique promotes diversity among students as an invaluable asset to the subject matter. The engagement of minorities or under-represented students will be enhanced through this method. Students will recognize the value of diversity in extending course material beyond their boundaries

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