AC 2007-2001: DEVELOPMENT OF ENGINEERING CONNECTIONS ENVIRONMENTS TO CONTEXTUALIZE ENGINEERING CONTENT MODULES

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Introduction

This paper describes the creation of a learner-centered, project- and problem-based environment for learning foundational engineering science topics; this environment has been named an *Engineering Connections Environment* (ECE). The ECE is implemented in the context of the sophomore year of the multi-disciplinary undergraduate engineering program at Arizona State University at the Polytechnic campus, in which a project topic guides the selection of five one-credit-hour engineering content modules. The ECE combines these content modules within a project-based learning environment; the modules are integrated with problem-based learning exercises, background pre-requisite material, and additional real-world applications. It is believed that the ECE approach will enhance students' engagement with the engineering topics and improve their ability to structure their own learning.

The concept of an ECE is broader in content but similar in structure to holistic content modules developed to teach numerical methods to engineering students;[1,2] these holistic modules include pre-requisite information, real-life applications, text material, simulations, and self assessment.

In this paper, we present the initial development and informal assessment of an Engineering Connections Environment. We first discuss the unusual curricular context for which the ECE has been developed, then describe in more detail the components of the ECE and how they work together. We then present the implementation of the ECE in the Fall 2006 semester and some assessment of the strengths and weaknesses of their implementation.

Curricular Context

The ECE has been developed in the context of a newly developed four-year multi-disciplinary engineering program at the Polytechnic campus of Arizona State University. In this program, all students learn a common body of engineering foundation material in their freshman and sophomore years, and then specialize through a primary and secondary concentration in their junior and senior years. Both semesters of the sophomore year employ the novel project/module course structure shown in Figure 1. In this structure, a project course is combined with companion engineering content modules that support the project; the project provides an integrating experience for the content. Four one-credit-hour content modules are loosely structured into a companion course, and a one-credit-hour content module is embedded in the project course. This curricular structure is implemented in a studio environment where projects and problems are done in collaborative student teams working with faculty mentors. In some primary concentrations, the project/module course structure may also be used in a junior or senior semester.

This model is adapted from the approach used at Aalborg University in Denmark;[3,4,5] the model provides curricular agility and supports engaged learning. Agility is achieved by changing the project topic from semester to semester in response to student interests, faculty expertise, and opportunities for collaboration with industry and the Engineering Program's broader constituency. This structure supports pedagogies of engagement[6,7] which include Problem Based Learning (PBL), project-based learning and cooperative learning; these pedagogies provide a better match to the learning styles of most engineering students than does the traditional lecture mode and have a positive impact on student persistence, academic achievement, and student attitudes.[6] PBL supports contextual learning in which principles are explored within a context; we believe that such learning improves a student's capability to transfer knowledge from its original context to other contexts.

ECE Structure

Figure 2 illustrates the concept of an ECE. We envision an ECE as a *project–contextualization–knowledge* integration triad. This model provides curricular flexibility through the selection of the project topic and content modules as well as an emphasis on individual learning. The ability to connect "real-world" projects to abstract material, while at the same time strengthening the linkage through contextual problems, is a significant advance over traditional content instruction.

As illustrated in Figure 2, the ECE consists of PBL activities, homework assignments, and supporting material that help students learn the module content and relate the module content to the project activity. Ideally, some of the PBL activities span multiple modules, which helps students to understand the connection between topics and how the topics are used in the real world. Some of the activities also connect the content learned in each module to the project; for example, theory learned in a module would be reinforced by homework covering a project-related application of the theory, and the homework then becomes the nucleus for a larger part of the project.

Fall 2006 ECE Implementation

The initial implementation of the ECE was piloted in the Fall 2006 semester. The project course met for two 110-minute sessions per week; the companion module course also met for two 110-minute sessions per week. All course sessions were located in an engineering studio environment. Students were divided into six teams of four or five students, and most of the project work was done in these teams. Each module is listed as a one credit hour course in the official course catalog; thus, students receive a grade for each module, and the module and grade will appear on student transcripts. 21 students were enrolled in the project course. Not all of these students were enrolled in all of the modules; due to differing levels of preparedness and success with the module prerequisites, some students were enrolled in a subset of the modules. The other sophomore-year courses taken by the students were traditionally structured.

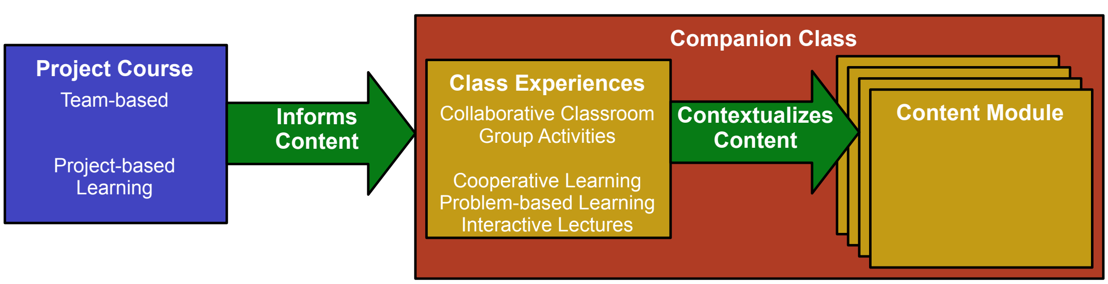

Figure 1: Project and companion module structure used in the sophomore year.

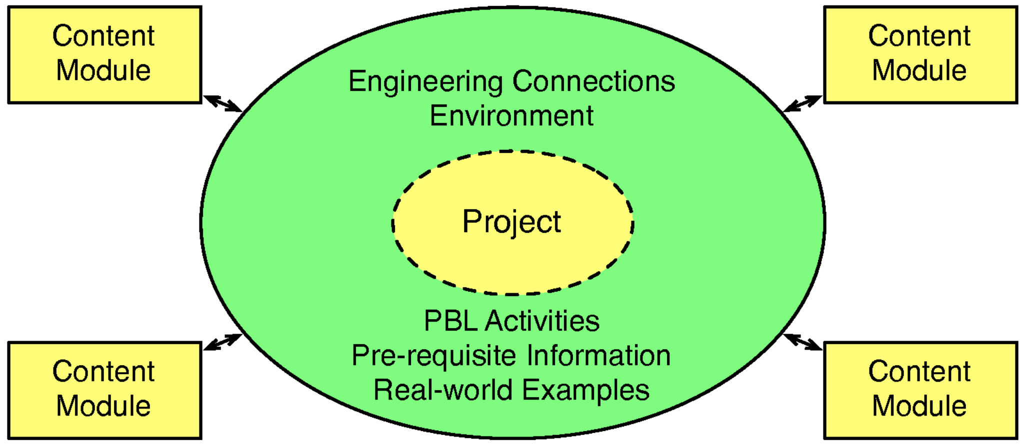

Figure 2: The Engineering Connections Environment provides learner centered context and integration for several engineering topics.

For this semester, the project was chosen as the design and prototyping of underwater robotic devices. The five companion content modules for the project were:

Mechanics: Dynamics Introduction to the concepts of force and moment and their relationship to the motion of an object.

Mechanics: Deformable Solids The behavior of solid bodies subjected to various types of loading.

Manufacturing Processes Introduction to manufacturing processes including basic operating principles, manufacturing process selection, and production economics.

Material Selection Application of materials science to design problems, including development of material indices and the use of the Cambridge Engineering Selector software to choose appropriate materials for mechanical design problems.

Instrumentation Introduction to instrumentation systems and components including transducers, associated electronics, and data acquisition and analysis.

These modules were selected both because they support the engineering content necessary for the project and because they integrate well together, providing many inherent connections between topic areas. This set of modules has a strong mechanical engineering orientation to support the project. (The set of modules selected for Spring 2007 has a systems/simulation orientation to support the Spring 2007 project.)

Each content module was supervised by a different instructor, and instructional activities were generally organized along module or project lines. The activities for each module (e.g. problem-based learning activities, homework assignments, etc.) were integrated into a semester-long plan.

The resulting plan was quite complex, integrating activities from several modules into each week; the plan was represented in a Gantt chart schedule that was color coded with each module and the project in a different color. Several of the PBL activities spanned two or more modules. Each module had individual homework assignments; the mechanics modules had common quizzes and tests, while the other modules had independent quizzes and tests. Student work was assessed independently for each module (since each is technically an independent one-credit-hour course), and students received a grade from each module instructor for their module. Students also received a separate grade for the project course.

One faculty member accepted the responsibility to coordinate the module activities and keep the schedule up to date. This faculty member also provided students with a weekly summary of assignments and due dates for all modules. Faculty coordinated their activities informally and, when necessary, as an agenda item in the weekly department faculty meeting.

Each module instructor took the lead in interfacing with students for their module content. Several faculty often attended the class on days when their module material was not scheduled; these faculty often provided secondary support for the module covered on that day, answering student questions and mentoring student group work.

None of the modules required students to purchase and use a textbook. This decision was made because, with a traditional approach of one textbook per subject, students would nominally be required to purchase five different books (i.e. one for each module); additionally, most textbooks are designed to support a one- or two-semester course structure, not a one-credit hour module. Some supporting materials were made available to students. The material selection module used portions of a textbook available on-line in the Knovel Library for reference and support; the instrumentation module used several on-line circuit analysis texts as resources.

Several problem based learning activities were developed that included information for both instructors and students. For instructors, the information includes scholarly background information, required supplies, and a description of the PBL activity. For students, the information includes preliminary reading, additional reading resources, preliminary questions, activity instructions, and follow-up questions. A sample activity developed to support the instrumentation module in the Fall 2006 semester is available on-line via the Connexions Project (`http://cnx.org`); other materials are currently being placed on-line as well.

Assessment of Fall 2006 ECE Implementation

Most of the student teams designed and prototyped robots that were judged by the faculty to have met the project objectives. Four of the six teams included an instrumentation component as part of their robot design. All teams fabricated part of their robot using a rapid-prototyping machine.

On the last day of class of the Fall 2006 semester (before final exams), students were given a survey to elicit feedback on the effectiveness of the project/companion class structure. The survey consisted of statements about the project/companion module structure; each statement had an associated Likert scale, with 1 corresponding to strongly agree and 5 corresponding to strongly disagree. The survey questions are listed in the Appendix. Twenty students participated in the survey.

Students felt that the modules and project supported each other well, as indicated by the few (four or less) neutral or negative responses to Statements 1, 2, and 3. Almost half of the students were neutral or disagreed that covering several topics together promoted understanding of each topic (Statement 5), although students agreed (no negative responses) that covering several topics together helped students understand the relationship between topics (Statement 6). Most students felt that working on several modules during a week did not promote understanding of the module material (Statement 7). About half of the students had difficulties with the schedule (Statements 9 and 10). Students were not strongly negative about the support materials provided (Statement 8), but a strong majority would prefer having one or more textbooks (Statement 13), and about half of them felt that not having a textbook hurt their understanding (Statement 14).

In addition to the survey, a focus group of eight students met to provide more detailed feedback; this meeting was held after the final exams for the module and project classes. Themes that emerged in the focus group include:

- There was a good fit between manufacturing processes, material selection, material properties, instrumentation and the project, and it was helpful to see similar material covered from different perspectives.
- Students learn better when there is strong a link between the project and the content of a module.
- It was helpful to see similar material covered from different perspectives by different faculty.
- The large number of different modules spread the students' focus. Students felt that the topics would be better understood if each module were covered in a single block of several weeks.
- The complex time schedule created time management issues that negatively affected student understanding; there was no warning or warm up for the time management challenges. Also, changes in the schedule as the semester progressed created difficulties for students.
- Hard copy (a book) is preferred to online material.

In summary, the assessment data indicated that the modules and project integrated well and provided enhanced understanding of the connections between topics. Students found that the complex schedule and the intermixing of different content topics made learning each topic more difficult; they expressed a strong preference for textbooks or other similar supplementary materials.

The student feedback from the Fall 2006 semester has been used to modify the implementation for Spring 2007. The schedule for the Spring 2007 project/companion modules has been structured so that the module embedded in the project continues throughout the semester; the four modules in the companion class are arranged so that two run concurrently during the first half of the semester, and two run concurrently during the second half. Each concurrent module meets either on Tuesday or Thursday, providing regularity and predictability to the schedule for the students. In addition, students will be provided with better supporting resources; an on-line text book will be used for one module, while traditional textbooks will be used for several others.

Conclusions

We have presented the development of an Engineering Connections Environment. Student feedback indicates that the structure does provide connections between engineering content areas. Student feedback also indicated that the irregular integration of modules introduced significant scheduling complexity that students found detrimental to their understanding and performance; this has been addressed by developing a more regular schedule that still allows module topics to be integrated together in the context of an overall project.

Based on our initial experience, we believe that an engineering connections environment could also be beneficial at the junior and senior level when students participate in concentration specific and capstone projects. We believe this structure could be extended to multi-disciplinary teams (e.g. a joint capstone project between engineering and business), in which the modules provide flexibility to structure different content for different groups and individuals participating on the teams.

1 Appendix

The questions on the student survey were the following:

1. The module topics were important for the project.
2. The material covered in the modules was used in the project.
3. The project helped me understand the need for the material covered in the modules.
4. The module topics fit well together.
5. Covering several different topics together helped me understand the material for each topic better.
6. Covering several different topics together helped me understand how these topics are related.
7. Working on several different modules during a typical week was helpful in understanding the material from each module.
8. The modules provided sufficient supporting resources (texts, on-line information, etc.) to help me learn the material.
9. The module schedule was clear-I knew when I needed to attend class.
10. I knew when homework and other assignments associated with the modules were due.
11. The modules left enough time at the end of the semester for me to concentrate on completing the project.
12. I used the material learned in Physics 121 in the Mechanics modules.
13. I would prefer to have one or more textbooks for the modules.
14. Not having a textbook for the modules hurt my understanding of the material.

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