Creating an Academic Learning Community Using a Multi-level Project

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This paper describes a multi-level, integrative, semester project involving students from two different engineering thermodynamics classes: Thermodynamics II, an applications oriented course at the junior level, and Advanced Thermodynamics, a beginning graduate course. The project was carried out in groups of five to six students with a mix from each class. A total of fifty-one students participated in the semester project. The primary goal was to engage students at different levels in an integrative experience requiring cooperative learning, research, synthesis and evaluation, and communication skills. The project also provided context and motivation for the subject matter in the respective courses. The paper describes the pedagogical framework and the assessment data gathered. In addition, attempts were made to facilitate effective group interactions and to form a "community of learners" beyond traditional class boundaries. These aspects are also discussed. The paper concludes with a review of lessons learned.

Project Overview

Students in an undergraduate section of Engineering Thermodynamics II and a graduate section of Advanced Thermodynamics were assigned to groups of five or six including at least two students from the graduate course in each group. *The overall learning objective of the project was for students to demonstrate ability to work effectively with a team to research, develop, and communicate creative, sound, and appropriate responses to an important societal issue*. This statement is consistent with the stated learning outcomes of the courses and with the program level outcomes of the mechanical engineering curriculum. The project required many levels of critical thinking, including synthesis and evaluation.

All groups were assigned the task to develop solutions to the following problem: *What mix of conventional and renewable energy sources should be in place in Iowa by the year 2015? Recommend actions that will assure those sources are in place at the desired time*.

The assignment involved several components, including

- compilation of resource materials based on library and internet research
- individual paper focusing on energy sources or technologies
- individual paper focusing on public policy issues
- draft recommendations and report outline
- final written report including executive summary
- fifteen-minute presentation

The assignments were paced throughout the semester and culminated with the projects being reviewed by a panel of outside experts. The students' project grades were based on both individual and group components, valued at 55% and 45%, respectively. The project grade counted as 25% of their respective course grades.

The undergraduate thermodynamics course was the second of a required sequence for mechanical engineers, and covered the topics of gas cycles, refrigeration and air conditioning, and combustion systems. The specific content learning objectives of the course were unchanged, and the semester project was accomplished as part of the design, teamwork, and communication objectives of the course. Some undergraduate students saw the project as an add-on, but in principle it was consistent with the stated course objectives. The graduate course is intended as a review and extension of undergraduate thermodynamics. The content objectives focus on the laws of thermodynamics, second law analysis, and applications. The course objectives include teamwork and communication, and projects are expected routinely as part of the course delivery.

Both formative and summative assessments were carried out at different stages in the process. Some were formal and some were informal. Expectations were laid out in terms of rubrics and numerous oral, written, and electronic communications. Students received specific formative feedback on each of their papers, a summative evaluation of each paper based on the prescribed rubric, and feedback on their draft recommendations. Summative assessment focused on the final reports and presentations, although feedback was provided during the development of each.

The coordinating team for the project consisted of the professor, a faculty member from the University Library, and an instructional technology specialist from the university's Center for Excellence in Teaching and Learning. The library component was set up to provide students with pathways to find and evaluate resource materials and to obtain feedback and consultation about sources. The instructional technology component included web-based communication appropriate to support the work of the student groups and the assessment.

Pedagogical Framework

Huba and Freed, in *Learner-Centered Assessment on College Campuses*[1] define assessment as "an activity, assigned by the professor, that yields comprehensive information for analyzing, discussing, and judging a learner's performance of valued abilities and skills." Stiggins[2] provides a similar definition for classroom assessment. Each reference makes a strong case that assessment is an integral part of pedagogy and that planning for instruction must involve a carefully integrated view of the critical relationship between assessment and pedagogy. Incorporating an integrative project, involving multi-level students, in completely separate courses was an ambitious undertaking. We attempted to see if we could achieve the type of learner-centered approach advocated in these and other references and create a type of pedagogy that is impossible to achieve within the confines of a single course.

Two main pedagogical ideas were used as the basis of the instructional design: *constructivism* and *cooperative learning*.

A *constructivist* approach[3] was taken by developing a problem that most students had not studied formally before. The students had to rely more on previous learning gained from media, discussion with others, and their own general interests rather than on coursework. This provided a sort of "leveling" between the undergraduates and graduate students and allowed them to construct new learning in their own ways. Individuals at both levels had differing backgrounds on the subject matter of the project and would construct new learning based on their prior knowledge. Also, the problem provided a context for learning in the classroom, and attempts were made throughout the term to help students link in-class learning with the project.

The problem was integrative and required thinking and research at many different levels. Initially, groups were encouraged to explore creative and "out-of-the-box" solutions. They were encouraged to investigate new and emerging technologies, energy sources that were as yet unproven, and concepts that might require a longer time frame than ten years. Once a broad set of ideas and alternatives were identified, the groups needed to begin focusing on concepts that might be more suitable in the near term. Further, the solution ultimately was to be focused on Iowa, so global and national issues needed to be put into that perspective. Thus, students quickly got involved in critical thinking and problem solving. Because the final product was to be one solution per group, they also needed to develop the group skills required to find consensus.

Thus, groups started with a wide spectrum of initial knowledge and had to progress fairly quickly from knowledge to synthesis and evaluation levels of thinking during the semester. This was a challenge that different groups handled in different ways. However, all groups came to grips with these issues because of the fact that the final product would be shared both on and off campus.

The principles of *cooperative learning* were incorporated explicitly in the design of the project. Each of the five necessary structures for effective cooperative learning from Johnson, Johnson, and Smith[4] were addressed explicitly.

- <u>Positive interdependence</u>. By the very nature of the assignment, all members of the group had a common goal for the semester's work. Their individual grades were heavily dependent on the final group product and they had significant individual investment in the final result. The initial assignment was for each group to develop an annotated bibliography of library and internet resources in technology, energy source, and policy areas. The compiled list was then shared among groups, creating some interdependence among groups. Within the groups, deciding on the topics of the two individual writing assignments and what each individual would do created a strong interdependence requiring discussion followed by resource dependence (jig-sawing). Each person in the group became an "expert" in some aspects of the over all problem relative to the other members. In order to create the final recommendations, all members had to share their specific knowledge and ideas.

- Individual accountability. Groups submitted periodic progress reports in which they summarized their efforts, assigned specific roles and responsibilities, and set goals. They reported both electronic and face-to-face meeting attendance. The jigsaw assignments held each person accountable, and group members were encouraged to review each others' work before submission. A mid-term assessment addressed individual contributions to the group, and the final assessment included students evaluating their own and others' contributions to the group effort. Also, significant individual accountability was built in because components of each student's grade were individual.
- Face-to-face interaction. Because the project was conducted outside of assigned class time, significant attention was paid to facilitating student interaction. First, all groups were invited to attend evening sessions near the beginning of the term to develop an understanding of the semester project. Near mid term, two large group forums were held to discuss issues and share ideas. Groups were encouraged to schedule weekly meetings, and attendance was monitored. The web-based course management system that supported the project was set up to facilitate inter- and intra-group discussion. Students used email to communicate directly with each other and with the instructor. Despite the attempts to facilitate interaction, this was one of the most challenging logistical issues for the semester.
- Social/teamwork skills. Active learning structures involving groups were used in each of the individual classes, and social skills were addressed directly in that context. It was assumed that students at both the undergraduate and graduate levels would need to learn about how to be effective in their groups, so class time was spent explicitly on this issue. The learning groups in the individual classes were used for discussion, brainstorming, problem solving, paired reading, etc. Specific attention was paid to attributes of effective group functioning, including interpersonal communication, listening, learning to be positive and supportive, conflict resolution, and encouraging all members to participate.
- Group processing. Specific attention was also paid to having groups assess their functioning and effectiveness. In part this was done through the progress reports, but it was addressed explicitly in class as well. Mid-term assessments included reflection on the groups and feedback was provided. Also, at times individual groups had issues that they brought up with the professor. Those were handled by first making sure that the group had used appropriate processes to try to resolve the conflict. When necessary, though, the professor intervened with individual students if their actions were harming the group and if the group couldn't resolve the issue.

The framework was intended to incorporate many of the best-practices of learner-centered pedagogy. The project integrated this pedagogy with assessment in a holistic manner. Although the project was complex and challenging, it was hoped that by establishing clear expectations, designing the learning experience carefully, and providing lavish formative assessment throughout, that the results would be of high quality and professional.

Project Assessment

In this section, various aspects of the formative and summative assessments are discussed. The discussion begins with a review of each of the course components.

Compilation of resource materials. During the initial phase of the project, each group surveyed web sites, books, articles, journals, visual media, etc., relating to energy sources, both conventional and renewable, energy technologies, and energy policy issues at the state, national, and international level. The students received instruction from the librarian who help support the project on how to find appropriate resource materials and how to evaluate their quality. They were also provided instruction regarding plagiarism. The groups developed annotated lists of high quality resource materials, including the full bibliographical citation and a brief description of the content and significance of each source. These were posted on the web to allow all groups access to the information. The bibliographical lists were reviewed for appropriateness by the librarian and the instructor. The student research was felt to be of high quality, and the compiled list is a resource that the university library is considering keeping on line for others to use and modify.

Individual paper on energy sources or technologies. This assignment required group discussion based on the initial research to identify five or six specific energy sources or technologies that would be the subjects of more intense research by individuals in each group. The group needed to reach consensus on what each member would study, and the members were told that the quality of their individual work would be important to the ultimate success of the group. The papers were 4-6 pages, and were to be written for a general audience consisting of college-educated people but not necessarily engineers.

A class period in the graduate course was devoted to developing the rubric that was used for evaluating the papers. The students were given five categories: appropriateness for the audience, organization and logic, objectivity, technical accuracy, and grammar and syntax. They then developed adjectives to describe excellent work with respect to each category of assessment. For example, appropriateness for the audience was characterized as understandable, informative, interesting, clear, minimal use of jargon and acronyms, practical, applicable, and relevant. These were compiled and distributed to the students to guide them in developing their papers for submission electronically.

This set of papers was reviewed extensively by the instructor, and an annotated electronic file with the evaluation and comments throughout the text as necessary was provided back to the students. The papers ranged somewhat widely in quality, professionalism, objectivity, and level. Each category of assessment was scored on a scale of 1 to 5, with 5 being the highest and signifying that the work exemplifies the desired qualities and 1 indicating that the work had few or none of the desired qualities. Total scores ranged from 11.5 to 24 out of 25, with an average of 20.2. Thus, most of the work was of high quality. Students were also provided a summary of overall observations about the writing to guide them in their future work.

Individual paper on public policy issues. The second paper focused on policy issues, and this phase of the project pushed students out of their "comfort" zones. They seemed to be quite content to do technical research and write technical papers, but the open-ended aspect of the policy issues made many of them uneasy. Specifically, students were asked to investigate issues related to state, national, and international considerations regarding energy sources, environmental matters, economics, social concerns, or other issues that play significant roles in determining energy policy. The papers were to provide necessary background for the discussion they were going to have in order to develop their final recommendations. Although detailed instructions were given as to the objectives and scope of the papers, groups struggled with this assignment.

The same rubric was used for the second paper as for the first. The papers seemed to be of higher quality over all than the first ones, and there was clear evidence that many individuals responded to the specific feedback they received on their first paper. The scores ranged from 13 to 25, with an average of 20.65. In both sets of papers, the graduate students out-performed the undergraduates as a group, although there were many excellent papers in the undergraduate group.

Draft recommendations and report outline. About two weeks before the final reports were due, the groups were required to submit a summary of the energy source mix they intended to propose, the actions they expected to recommend, and a brief rationale for their draft recommendations. They were instructed to do the best they could to develop a consensus among the group members and to narrow the conversation. The drafts were not graded, but each group was provided with specific feedback by the instructor.

To aid in the process of developing the recommendations, two forums were held brining students from each class and all project groups together. Each group was asked to have at least one representative at the forums, and many groups attended in force. The forums were structured to allow groups to give brief presentations about their work to that point, share ideas about strategies to impact energy use, discuss the state of various alternative sources and technologies, and to ask questions. Minutes of the sessions were provided to the groups. The forums helped build community among the students in the two classes.

Final report. The final report was considered one of the main deliverables representing the culmination of the semester-long effort. As such, it was emphasized to the students that the reports were to be professional and of high quality. The audience was professionals, although not necessarily energy experts or engineers, but people interested in and informed about public policy issues related to energy. The reports were submitted electronically and were posted on the course web site for students and the external reviewers to view. The reports were completed two weeks before the end of the semester to allow time for the groups to develop their final presentations.

The written report rubric was modified slightly for use in assessing the final papers. The reports were uniformly of high quality and met the expectations of the project. There was clear evidence of each group synthesizing the work of the individuals into a coherent final product. The writing was of higher caliber than the individual reports, and attention was obviously paid to the specific expectations given in the final report guidelines. The scores ranged from 21 to 25 for the final reports.

Final Presentations. Each group prepared a 15-minute presentation to be given during class. The presentations included appropriate PowerPoint visuals and were recorded. The students were told that the audience for this talk was assumed to be knowledgeable about energy systems and energy issues, but not expert on any particular technology or policy. The talk was to focus on the group's analysis of which technologies and sources to recommend and the actions recommended to reach particular goals. Students were provided written guidelines and class time was used to discuss what would make these presentations effective. Instruction was based on materials provided by the English department instructors for the university's communication-across-the-curriculum program. The instructor reviewed planning outlines of the talks provided by individual groups and provided feedback. The presentations were given during the last week of the class and were immediately posted on the course web site for students and external reviewers to view.

Assessments were based on an oral report rubric that guided the students' work. Assessments of each talk were completed by the instructor, other students in the class, and the external reviewers. Generally, the presentations were professional in quality, although there was variation from group to group. The scores ranged from 14 to 20 out of 20 points possible. The main issues identified were poor transitions within the talk, rote delivery by reading notes, and in a few cases insufficient introduction and/or conclusion of the talk. The students would have benefited from having had more opportunities for oral presentation, including feedback, but this was not considered feasible within the constraints of the project.

The assessment of each of the course components provided a meaningful set of experiences and opportunities for learning. As noted, all of the assessments included numerous formative aspects that would result in improvement as the semester progressed. As noted in each case, improvement was seen and the final products and summative assessments bore that out. The discussion now continues with consideration of the overall evaluation of the project and its success.

External Evaluation. The external reviewers all had particular expertise and experience in energy systems and energy policy. They volunteered considerable time to review and comment on the group efforts and on the project over all. Each reviewer was asked to review 3-4 projects, including the presentations, reports, and executive summaries. Their input was solicited through evaluation of the presentations and reports and through participation in a two-hour web-assisted telephone conference in which the projects were discussed. The session involved a conference call and an on-line component in which the computer was used as a "flip chart" to record the important ideas in a way that all participants could see instantly. The first hour was spent on general discussion of project quality and sharing what the reviewers thought were important aspects of the energy issue from their perspectives. The second hour focused on strengths and weaknesses of specific projects and an evaluation of the project over all.

The reviewers were generally very complimentary of the quality of the student work. They had many specific comments for improvement, but those were offered in the context of the reviewers' over all positive response. The external reviewers were all excited that a large group of students had spent time on such an ambitious and important topic and encouraged that this sort of activity be done again. They expressed willingness to participate again and offered to be resource people for future groups.

Student Evaluation. Students were asked to respond to two specific questions about the project over all and to rate themselves and their fellow group members on their contributions to the group effort. Table 1 lists the response to the question: "Would you recommend a semester project of this type for ME 332 or ME 530?" The vast majority in both classes felt the project was worthwhile. The response from the graduate section was slightly more positive than from the undergraduate section. Reasons given to continue the project focused primarily on the value of learning about alternative energy technologies and policies, learning how to do research, learning how to present one's work, and learning how to work with others to achieve a common goal. Even among those who said the project shouldn't be continued, most said they learned a great deal. Thus, the over all learning objectives of the project appear to have been met. The reasons given for not recommending continuation focused primarily on issues of work load, scope of the project, and relevance of the topic to other course material.

	Yes	No
ME 332	68.18%	31.82%
ME 530	75.00%	25.00 %
Combined	71.43%	28.57%

Table 1. Responses to the question: Would you recommend a semester project of this type for ME 332 or ME 530?

Students were also asked to provide suggestions should the project be done again. The main issues raised were to find ways to scale the project back or focus the experience more. Other issues involved logistics and timing. Some suggested more specifics be given about the assignments and to move the timeline to earlier in the semester. People commented about the difficulties of having two classes involved, including scheduling and the levels of the two groups. Finally, some suggested tying the project closer to the material in covered in class, requiring more individual accountability, and giving more credit of the project. The suggestions were constructive and will help if a similar project is tried again.

Lessons Learned

The following is a summary of the main lessons learned in this semester project experience.

1. When given a challenge and support to meet it, students will rise to the occasion and do exceptional work. This was illustrated by the quality of the final reports and

presentations and was confirmed by the outside reviewers. It should come as no surprise, but often we set our expectations lower than we might.

2. A semester project involving so many assignments, difficult logistics, and different levels of students requires a great deal of effort on the part of students and instructors. The students received credit for the project, and most believed they were duly compensated for their work. For the instructor, the sheer volume of assessment required considerable diligence and was very demanding. Because the project was structured outside of each course, it was nearly equivalent to teaching an additional course. Although the instructor work load would be reduced in subsequent offerings, it still would remain significant. With the many other demands on professors, this issue is significant, and may be the limiting factor in the use of such ambitious integrative projects.
3. External review provides a significant dynamic in such a project. As the semester progressed, the students became acutely aware that their final products were going to receive scrutiny from experts in the field. In fact, they realized that some of the resource materials they were using were developed by the individuals who would be reviewing their work or the organizations they represented. I believe this led to a higher quality of professionalism in the final reports and presentations than might otherwise have been achieved. In addition, the fact that external reviewers would be scrutinizing the work provided an important outcome assessment tool for the department to use for accreditation.
4. A semester-long effort requires sustained student motivation and commitment. Near mid term, some challenges occurred because of commitment. Several undergraduate students who were doing poorly decided to drop the course. Unfortunately, the drops were concentrated in three particular groups, resulting in two groups combining and the third having only three people. Attrition is one of the potential problems in semester-long projects that require creative solutions and can compromise the experience of students.
5. The project established a community of learners that transcended the boundaries of traditional courses and levels. The sustained nature of the interactions over an entire term created strong bonds within the groups, which were reflected in the individual evaluations and the student comments. The very nature of the positive interdependence of the assignments created these bonds. Interactions among groups and between the classes were more sporadic, and it is doubtful that much community feeling was developed at that level. If this experiment were tried again, additional attention would be paid to building community more broadly through joint activities such as seminars and social events.
6. A carefully-designed learning experience that incorporates proven pedagogy and assessment techniques results in high achievement of student learning objectives.

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