Development of resource modules to enhance project based learning in an interdisciplinary engineering course

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ABSTRACT.
Five resource modules were developed for use in a multidisciplinary engineering course to enhance successful implementation of semester-long team projects. The modules consisted of research articles, reports, book chapters, and videos and provided technical information related to projects to bring students from different discipline up to the same level. Use of these resource modules by 46 students in a sustainability engineering and international development course was evaluated. An approach consisting of both quantitative (pre-and post-test, survey) and qualitative (focus group discussions) methods was used for data collection. Pre-and post-test results showed an increase in student learning in the course and resource modules were found to be useful to multidisciplinary teams for achieving their project implementations. The assessment techniques were complementary, thus helping in identifying strategies for improving teaching-learning in a multidisciplinary engineering environment.

Keywords. Resource modules, Education, Engineering, Sustainability

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Introduction

The importance of sustainability has become evident in recent years because of such concerns about impact of human activities on the natural world around us, so integrating sustainability into engineering education is crucial since engineers play critical roles in addressing sustainability challenges. In higher education, efforts to incorporate sustainability have included adding modules to existing courses, developing new courses, organizing guest lectures and departmental or university-wide seminars, developing centers and institutes related to sustainability, and providing opportunities for research in sustainability. However, in spite of all these efforts, institutions often struggle to find optimum methods for educating students about social, environmental, and economic realms of sustainability, and this struggle is mainly due to the interdisciplinary nature of sustainability.

Accreditation requirements and global market also require engineering programs to find creative ways to incorporate multidisciplinary team skills into their curricula (DePiero, 2007). Multidisciplinary team projects help students to learn from one another, make meaningful connections across different subject areas, and gain perspective, but the literature reveals inherit barriers such as attitudinal resistance and different levels of knowledge and skills, often resulting in lack of communication among team members (Iliffe, 2008). Project design and implementation often require a deeper understanding of technical concepts but, because of lecture time constraints, project diversity, and multidisciplinary student backgrounds, it is sometimes difficult to cover the detailed technical concepts needed to effectively meet project objectives. In addition, with a lack of specific knowledge, students may struggle to gather the information appropriate to the projects, in turn resulting in disinterest or lack of participation in project design and implementation.

To address these issues, we developed resource modules that permit students to learn technical concepts at their own pace outside the classroom and expand their knowledge beyond their major field of study. The intended function of the modules was to quickly provide access to the most appropriate materials so that students can more effectively direct their focus and efforts on the projects rather than search for relevant material. Resource modules were intended to provide students lacking background knowledge an introduction and an explanation of concepts without needing to search textbooks to obtain the information. The goal of this project was to investigate how resource modules could enhance project-based learning in a multidisciplinary engineering course.

The specific objectives of this project were:

1. To explore student understanding of sustainability and its implementation across various engineering systems, and

2. To evaluate student perceptions about introduction of resource modules to supplement the projects.
Methodology

The focus of this study was a sustainability engineering and international development course taught at Iowa State University. The audience for this elective course, offered to all engineering majors, was comprised of seniors and juniors engineering students. The average class size was 40 students. The course consists of six lecture modules (SB: Sustainability Background; ES: Energy Systems; WWS: Water and Waste Systems; AFS: Agricultural and Food Systems; BIS: Building and Infrastructure Systems; ST: Sustainability Tools) and a semester-long team project. Performance on a team project focused on the application of sustainable engineering principles in the context of developed or developing world scenarios constitutes 60% of the course grade. The other forty percent of the course grade was based on assignments and quizzes related to the lecture modules. In addition to lectures and class discussions, experts in appropriate fields were invited to deliver guest lectures. The three credit hour class met weekly for two 50-minute lecture sessions and one 110-minute laboratory session each week. The diverse teams were formulated based on students’ majors and their preferences for the project.

The resource modules provided foundational knowledge of the concepts relevant to projects. In the past students have expressed concerns about finding material to study for their projects. For example, a computer engineer might not have knowledge about how corn ethanol is produced while an agriculture engineer would understand the process. Thus, to bring students from different disciplines to the same level the following strategy was implemented. Resource modules consisted of two type of resources: reading material and videos. The reading materials were mostly comprised of reports, peer-reviewed articles, and book chapters. Online video resources were provided to generate interest and engagement with the topic. All resources were uploaded to the course website. Each project had its own set of resources accompanied by a resource guide. The guide listed the resource name, the relevance of the material to the project, and the number of pages that should be read. Most videos were short (5-10 minutes) so that students would remain interested. For longer videos, students were directed to the video time interval that should be watched to gain information relevant to their project. The resource modules prepared students for the laboratory class and helped in generating productive discussion with the team members so that they could make faster progress on their projects.

A mixed-method approach with sequential design was used for the assessment. Both qualitative (focus groups) and quantitative (survey and pre- and post-assessment) techniques were used for this purpose. Pre-and post-tests were used to evaluate knowledge gained in the course and data was collected both at the beginning and near the end of the Fall 2015 semester. The pre-and post-tests were comprised of 20 multiple-choice questions related to student understanding of sustainability concepts taught in the course. Focus group discussions and surveys were used to analyze student perceptions regarding resource modules and the overall course, and data was collected near the end of the Fall 2015 semester. Focus group questions were developed after analyzing data from the surveys along with having conversations with the instructors of the course. The survey used a five-point Likert-type scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree) and opened-ended questions. The focus group planning kit was used to design the focus group discussions (Morgan & Krueger, 1998). Two focus group discussions were conducted. Both an experienced moderator and an assistant moderator facilitated the discussion and took notes. The focus group discussions were recorded and transcribed.
Results and Discussion

Pre and post-test

Response rate for the pre-and post-test was 61%. On average, a 26% increase in students’ knowledge level of the subject matter during the course was observed. The average percentage of questions answered correctly in the pre-and post-test were 57.1 and 83.4% respectively, indicating that learning gains were associated with the course. In only one question was a decrease of 3.6% in post-test score compared to pre-test score was found (Fig. 1). In total, seven students gave wrong answers to the question “Burning which fuel produces the least amount of carbon dioxide per unit of energy?” in the post-test. However, five of them gave the correct answer to this question in pre-test. This indicates that students were uncertain or confused about the concept after it was taught. Overall, results from pre-and post-test showed learning gains in the course and also demonstrated an increase in understanding of the foundational concepts after taking this course. In the future, attempts will be made to go beyond testing conceptual understanding and developing a comprehensive set of questions covering foundational knowledge as well as application of concepts.

![Figure 1](image.png)

**Figure 1.** Students’ response to pre-and post-test by question and module type. Note: Lecture Modules: AFS: Agricultural and Food Systems; BIS: Building and Infrastructure Systems; ES: Energy Systems; SB: Sustainability Background; ST: Sustainability Tools; WWS: Water and Waste Systems

Survey and Focus group

The response rates were 53% for the survey and 26% for the participation in focus group discussions. Results indicate that students thought guest lectures, the modular format, and the diversity of topics covered in the course were helpful to their learning. However, students would have appreciated more information on sustainability in the context of engineering and engineering design. Only 35% of students agreed that the resource modules helped them with project implementation, while 50% of the students gave neutral responses. Focus group data analysis showed that students liked the resource modules and found the reports and the videos to be most useful, but some students suggested that more
direction and guidance on using resource module should be provided. Additionally, modules on materials related to cost analysis and life cycle analysis were requested. Resource modules both saved their time and decreased the inherent complexity of the interdisciplinary projects. They also increased the confidence levels of students and reduced their frustration in not understanding certain concepts outside of their personal fields of study. These effects also brought students from various disciplines to similar knowledge levels and helped them better understand one another’s perspectives as they explored solutions to some of the challenging sustainability problems. Students found the experience of working with multidisciplinary teams beneficial and had increased interest in projects developing innovative and sustainable solutions to real-world problems. This was the first time that resource modules were introduced into the course, and this presents numerous opportunities for future improvement.

**Conclusions**

The study used pre- and post-tests to monitor student learning and survey and focus group discussions to evaluate student perceptions about the course. The assessment techniques used in this study were complementary, aiding in the identification of strategies to improve teaching-learning in multidisciplinary engineering environment. Pre- and post-test results showed significant knowledge gains, and qualitative data provided insight into students’ perceptions about the course organization, resource modules, and projects. Focus group discussion data showed that technical resource modules were found to be useful in project implementation. These modules can also be used as supplemental materials for other similar engineering courses because they combined foundational concepts with some specific engineering information and equations. Successful implementation of course projects can help students to build sustainable futures by creating, sharing, and applying knowledge, resulting in continuous improvement in teaching endeavors. In the future, the impact of resource modules on student ability to design and implement their projects will be evaluated. This proposed approach enhances willingness of students to work across a variety of domains, and it can also be implemented for use in other engineering courses dealing with diverse student backgrounds.

**References**