Understanding engineering students' perceptions and knowledge about sustainable development and sustainability

B. Sharma[a], B. Steward[b], S. K. Ong[c] and F. E. Miguez[d]
[a] Post-doctoral Research Associate, Department of Agronomy
[b] Professor, Department of Agricultural and Biosystems Engineering (bsteward@iastate.edu)
[c] Professor, Dept. of Civil, Construction and Environmental Engineering (skong@iastate.edu)
[d] Assistant Professor, Department of Agronomy (femiguez@iastate.edu)
Iowa State University
Ames, Iowa, 50011

Abstract

The Sustainable Engineering and International Development course was first offered to engineering majors at the Iowa State University (ISU) in 2005. The course is focused on describing, discussing and comparing the key concepts of sustainability, sustainable development and sustainable engineering. In 2005, sustainability was not a major part of the engineering curricula and students had little to no knowledge about these concepts. Nine years later, sustainability has become an integral part of our daily lives. In this study, we wanted to understand student perceptions, knowledge, and understanding of sustainability, sustainable development and its implementation across various engineering systems. The assessment techniques used for the study were a pre-test and a survey at the start and end of the semester, respectively. Survey results indicated that students' ranking on usefulness of the course modules varied over the years mainly due to different engineering majors of the students in the class with diverse learning styles and pre-existing knowledge. The results of the pre-test indicated that students have knowledge about basic sustainability concepts, thus the difficulty level of the pre-test was low. In the near future, focus group discussions along with the survey will be conducted to better understand student perceptions on the effectiveness of the teaching methods and overall course materials. In addition, a post-test will be conducted for the questions set developed with input from experts in specific subject areas.

Keywords: Sustainability, Engineering, Education

Introduction

Higher education institutions have acknowledged their responsibility towards achieving goals of sustainability, as they play a major role in preparing future professionals.[1] Therefore, colleges and universities are focusing on campus sustainability as well as promoting sustainability across the curriculum for different majors, fields of study, and courses.[2]. Engineering students were introduced to the concept of sustainability about 25 years ago after a common consensus was reached among professional engineering associations on the importance of sustainability in this field.[3] Initially, sustainability education was integrated into civil engineering and later to environmental/chemical engineering programs. But with increased environmental concerns, the recognition of the need for sustainability in other engineering disciplines grew.[4]

Each institution has their own interpretation of sustainability engineering and its application in their educational programs. The courses in sustainability engineering offered by different institutions covers different aspects such as alternative and renewable energy, watershed sustainability, environmental sustainability, sustainable infrastructure and environment, climate change and life cycle impact assessment. But institutions are still working towards finding effective ways to educate students about sustainability in relation to engineering.[2] Successful implementation of such courses requires collaboration of faculty from different departments to develop and modify curricula to educate students about social, environmental and economic realms of sustainability.[4] The major barrier is bringing together skills and knowledge from different disciplines, which is neither easy nor clear.

To address sustainability on a global context and its requirement in developing countries, the Sustainable Engineering and International Development (SEID) course was developed and first offered to engineering majors at the Iowa State University (ISU) in 2005. The course consists of six lecture modules on sustainability background, sustainability tools and life cycle assessment, sustainable water and water systems, sustainable energy systems, sustainable agricultural and food systems and sustainable building systems. In 2005, sustainability was not a major part of the engineering curricula and students had little knowledge about these concepts. Nine years later, sustainability has become an integral part of academic programs as well as our daily lives. At ISU, the Office of Sustainability which is supported by several university committees, teams and organizations, aims to educate and involve every member of the ISU community in sustainability efforts. Sustainability has been integrated as part of the academic curricula and research endeavors including programs such as the graduate program in sustainable agriculture, Center for Sustainable Rural Livelihoods, and a sustainability minor.

Students' background knowledge and skills about sustainability and its implementation across various academic programs vary widely depending on their experience and major of study. Pre- and post-testing is a widely accepted and viable method to quantify the knowledge attained by the students with diverse leaning styles and educational backgrounds.[5] The pre- and post-test are administered at the beginning and end of the semester, respectively and a comparison of the post-test scores with pre-test scores enables quantification of the success of a program in increasing a participant's knowledge.[6] The pre-test helps to quantify prior knowledge and skills and helps the students as well as the instructor to direct their efforts towards productive learning outcomes. An end of the semester, course survey is also an important tool for student feedback regarding methods of instruction, course content, and students' overall experience. Students' feedback is crucial for improving teaching methods and enhancing the learning process for the students. The specific objectives of this study were to:

1) Evaluate students' perceptions about the SEID course and the teaching methods by conducting surveys at the end of the semester.
2) Assess students' knowledge and understanding about sustainability and its implementation across various course modules by administrating pre-test at the beginning of the semester.

Methodology

The SEID course is comprised of six lecture modules and a team project. Team projects, constituting 60% of the course grade, are focused on the application of sustainable engineering principles in the context of developed or developing world scenarios. Forty percent of the course grade is made up of assignments and quizzes from the course modules. In addition to lectures and class discussions, experts in their field were invited to deliver guest lectures. Because of the interdisciplinary content and structure of the course, the course is open to students of different engineering majors. Each week, the three credit hour class meets two times for a 50 minute lecture session and once for a 110 minutes laboratory session.

Institutional Review Board (IRB) approval was obtained for the study. The pre-test comprised of simple, short and course-specific 20 multiple choice questions to evaluate students' knowledge prior to the course. The questions span topics covered in the six modules of the course. Participation in the pre-test was voluntary and students completing the pre-test earn an extra credit of 1% increase in the quiz grades. Information collected was kept in a password protected computer. The course instructors and others had access to the data after participant names were removed.

In the years 2009, 2011, 2012 and 2013, at the end of the term, students completed an anonymous survey to rank the usefulness of the individual modules using a five to one scale. Rank five indicated the module was critical for the understanding of sustainability concepts and rank one indicated the module was not useful. In addition, survey also had questions to indicate students' perceptions about the course, course content, teaching effectiveness and self-assessment questions. The scale used for ranking the questions was strongly disagree, disagree, neutral, agree and strongly agree.

Results and discussion

End of the term semester questions were categorized into: questions about the course content, questions about course difficulty and workload and self-assessment questions. Overall, the survey results indicate no specific trend in the usefulness of each module over the years. The majority of students perceived the individual modules to be useful, very useful and critical for their learning. On an average the overall ranking given to modules was not very different therefore results for one module (Agriculture and Foods Systems (AFS)) is discussed. Figure 1 shows the ranking given by the students to the AFS module over the years. It was found that the percent of students that ranked AFS module as very useful and critical increased over the years. The understanding of each module by students could also be dependent on their major of study. In 2013, 42, 33, 14, 8 and 3% of students were from civil, agricultural and biosystems, electrical, mechanical, and chemical engineering, respectively and whereas in 2011, 68% of students were from civil engineering and rest were from computer, chemical, electrical, agriculture, agricultural and biosystems, and construction engineering. Some of these majors offer courses related to sustainability, therefore with variation in number of students from different majors, the perception of students on usefulness of each module might vary. Insufficient data was available to correlate the survey data collected over the years to student majors and student classification (sophomore, freshman, junior and senior). We believe that these factors affect the student

ranking for a module and its components, therefore in future, student major and classification data will be collected as part of the survey.

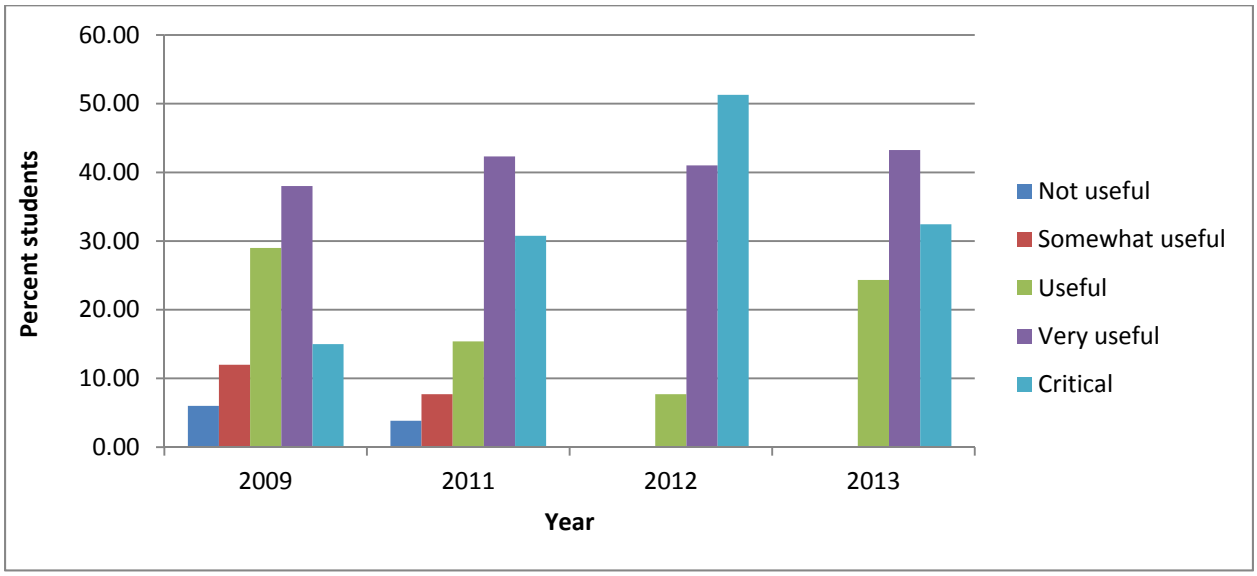

Figure 1. Students' evaluation response (percent students) on the usefulness of the agriculture and food systems module over the years

The students' responses to the self-assessment survey questions related to their perception about the course, method of instruction, and ability to consider key concepts of sustainability in relation to engineering demonstrated a positive outcome over the years. On average, 14, 56 and 29% of students gave neutral, agree and strongly agree rankings to the question about the relevance of material presented in the course to the practice of engineering today. Similarly, 2, 6, 17, 46 and 30% students on an average strongly disagreed, disagreed, neutral, agreed and strongly agreed that the course improved their knowledge of sustainability, sustainable development and sustainable engineering. In addition, the students' responses to a related question about if the course expanded their knowledge of engineering and sustainability to areas beyond their majors resulted in 30 and 58% students giving strongly agree and agree ranking, respectively. These results showed that to a large extent the course was successful in achieving its objectives and intended learning outcomes. Overall 1-20% of the students disagreed (disagree and strongly disagree) to some of the survey questions that could be attributed to the students pre-existing knowledge and experience with sustainability. All majors have incorporated sustainability across their curriculum either by introducing new courses related to sustainability or incorporating sustainability concepts into pre-existing courses. Therefore, it is crucial to understand students' pre-existing knowledge and skill sets to make definite conclusions about their learning and enhance the course further by editing/updating the course modules, if required. On average, 53 and 22% of the students agreed and strongly agreed, respectively, that the modular format of the course was appropriate and worked well for their learning. Students' responses to the question about if the information attained from the course will be used in the future resulted in an average of 2, 9, 21, 51 and 17% of students strongly disagree, disagree, neutral, agree and strongly agree, respectively (Figure 2).

Results from the survey did not capture all the elements of students' response to the course and was not sufficient to pinpoint improvements areas. The focus group approach is a qualitative research method with "a carefully planned series of discussions designed to obtain perceptions on a defined area of interest in a permissive, non-threating environment."[7] The open and interactive setting of the focus group provides good understanding of the students' beliefs and experiences.[8] In addition, focus groups provide opportunity to evoke more specific responses and gather 'rich data' which is not possible through the use of surveys.[9] However, the small number of participants in focus group is not representative of all the students enrolled in the course. Integration of qualitative research approach such as the focus groups with survey improves the quality and enhances the validity of the results.[10] These two approaches complement each other and strengthen the ability to draw conclusions from the study. Therefore, in the future, focus group discussion with surveys will be conducted to get detailed feedback from students and to better understand students' perceptive about the course.

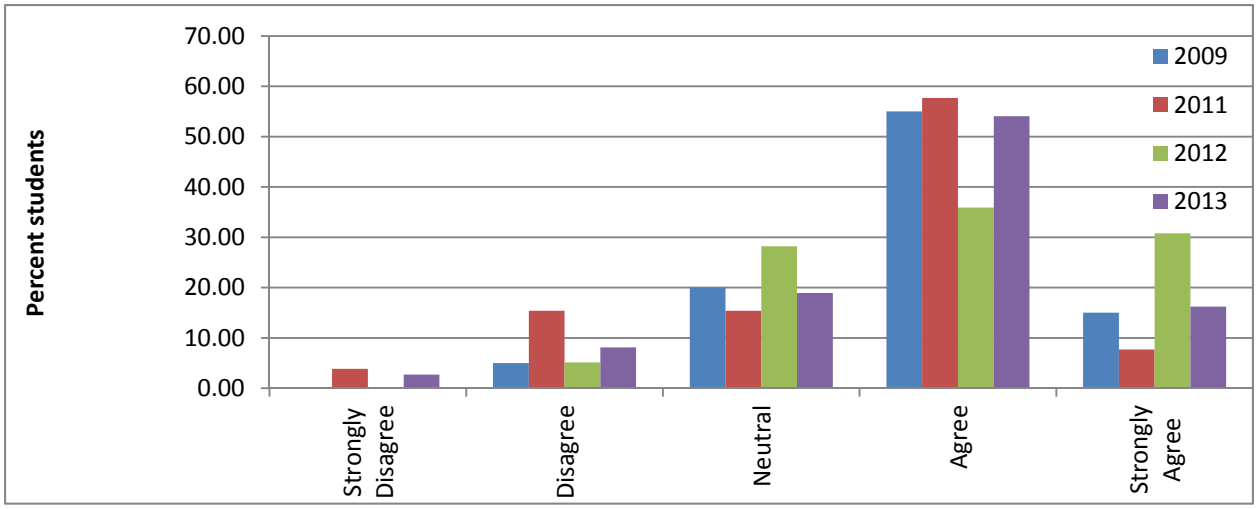

Figure 2. Students' evaluation responses (percent students) over the years to the question: Do the students anticipate using information from this course in my future career?

Twenty multiple choice pre-test questions were developed with 3-4 questions from each module. An example of questions from each module is presented Figure 3. The questions were developed to encompass the concepts of sustainability and its application covered in the module. Out of 47 students enrolled in the course in the Fall 2014 semester, about 93% completed the pre-test. The difficulty level of the test can be measured by the percentage of students who got the answer correct (ranging from 0 if no one answered the question correctly to 1 if everyone answered correctly). The difficulty level of 0.5 is considered ideal but may vary depending on the subject area.[11] It was found that the difficulty level of pre-test conducted for the present study was low (Figure 4). This questionnaire was the first attempt to gather data on students' knowledge and understanding of the course modules. In the future, attempts will be made to go beyond testing basic understanding of students and developing a comprehensive question set covering foundational knowledge as well as complex concepts. In addition, as students demonstrate that they have a good understanding of the general/basic concepts, lectures should focus more on application of sustainability across engineering systems.

Figure 3. Examples of pre-test questions

Module-1: Background (global sustainability challenges, local challenges, appropriate technology, engineering design process) and Sustainability Concepts

1) Sustainable engineering is a process of designing or operating systems such that they
   A. Solves immediate problem to fulfill short-term needs of the society
   B. Reduces risks to health and safety of employees
   C. Uses energy and resources at the rate that does not compromise the natural environment
   D. Reduces number of operations in a process to decrease operating cost of the system
   E. Don't know

Module-2: Energy Systems

2) Which of the following is the primary reason for rise in gasoline prices over the last several decades in the United States?[2]
   A. Growing percentage of gas stations owned by large corporations
   B. Increasing oil wells discovered overseas
   C. Food shortage around the world
   D. Increasing global demand for oil
   E. Don't know

Module-3: Agriculture and Food Systems

3) The main goal of Green Revolution was
   A. To decrease population growth in developing countries
   B. Introduce western culture and values in the developing countries
   C. Establishment of economic equality among the people
   D. Increase agricultural output
   E. Don't know

Module-4: Sustainability Tools, Life Cycle Assessment

4) The term TEA in engineering economics refers to
   A. Training Effectiveness Analysis
   B. Transportation Engineering Analysis
   C. Techno Economic Analysis
   D. Transportation Engineering Agency
   E. Don't know

Module-5: Water and Waste Systems

5) What is the primary reason for hypoxic areas (low-oxygen areas) in the Gulf of Mexico?
   A. Oil spills in the Gulf of Mexico
   B. Addition of fertilizers from agricultural activities
   C. Ocean overfishing
   D. Offshore oil drilling
   E. Don't know

Module-6: Building and Infrastructure Systems

6) Which of the following buildings at the Iowa State University have been LEED (Leadership in Energy and Environmental Design) certified?
   A. Memorial Union
   B. State Gym
   C. Environmental Health and Safety Services building
   D. Durham Center
   E. Don't know

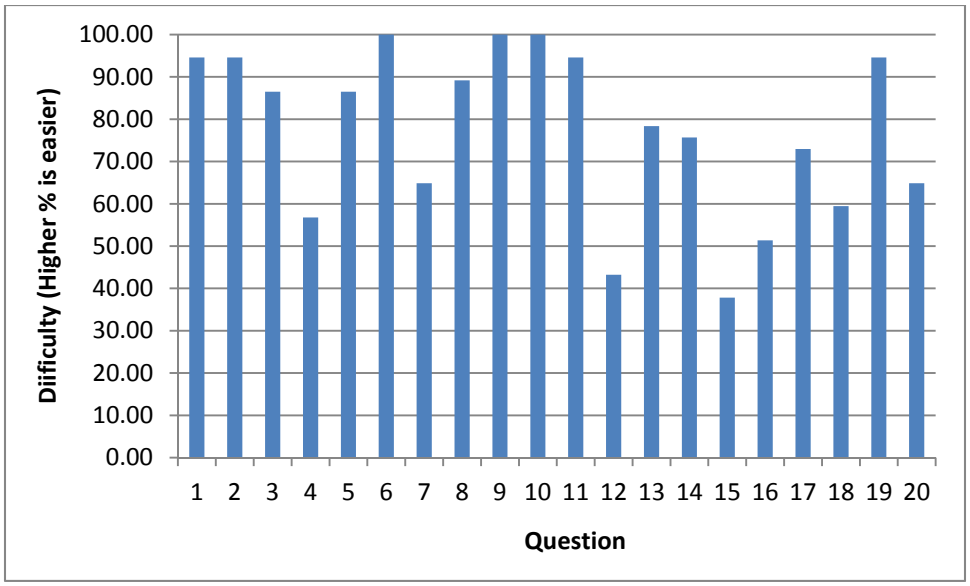

Figure 4. Difficulty level of the pre-test by question.

Through evaluation of students' responses to the specific question from each module, it was found that 14% of the students were not able to identify the federal agency in the U.S. that oversees environmental regulations. This was a straightforward question but still 3% of students opted for choice B (Natural Resources Conservation Authority) and 11% of the students opted for choice E (don't know). Forty three percent of the students were not aware about the percentage of world resources consumed by the U.S. Substantial number of students understood the steps involved in the engineering design process and meaning of sustainability engineering. All the students demonstrated knowledge about types of renewable energy sources and transportation fuel made from corn. The question about the primary reason for rise in oil prices and the energy source most widely used for electricity generation in the U.S. was answered correctly by about 85% of the students. The students were not sure about the country that is the biggest emitter of the greenhouse gas (CO_2). Eleven, 64 and 22 % of the students opted for choice E (don't know), choice C (China) and choice A (United States), respectively. The correct answer for this question is dependent on time period: until 2006 U.S. was the biggest emitter of CO_2 but after that China overtook it. The results from AFS module questions revealed that students knew about sustainable agriculture practices and understand the meaning of genetically modified organisms. On the other hand, students were not aware of the Green Revolution as only 43% of students answered the question correctly and 28% opted for choice E (don't know). The question on which state produces the most corn, 19% thought it was Nebraska and 3% opted for choice E (don't know). The sustainable tools and life cycle assessment module questions showed that only 75% of the students knew the first law of thermodynamics and 8% opted for choice E (don't know). The full form TEA (Techno Economic Analysis) was correctly answered by only 40% of students. The response of students to the water and waste systems module questions showed that 51% of students knew the primary reason for hypoxic areas in the Gulf of Mexico and 72% knew the causes for turbidity in water and 60% were aware of that agriculture sector consumes the largest amount of water. For the building and infrastructure systems module question, 94% of the students understood what Leadership in Energy and Environmental Design (LEED) rating reflects and 70% of students knew that State Gym at Iowa State University is LEED certified. Overall, results from the pre-test showed that students responded well to the

fundamental/foundational questions. However, weak performance was mainly for the questions bounded by time which indicates that students don't have up-to-date information. The results also indicate that the pre-test had low difficulty level and thus yielded higher scores. In addition, as students showed proficiency in understanding of basic concepts related to sustainability, some of these topics should be replaced by another topic or adjusted in the level of complexity or adjusted in the time spent on the topic.

Conclusion

Increasing sustainability knowledge among students is a common goal of colleges and universities. The SEID course is a multi-disciplinary course with respect to the course content as well as students enrolled in the course over the years. End of the semester survey data collected for the years 2009, 2011, 2012 and 2013 were analyzed to understand usefulness of the six modules taught in the class and students perceptions about the course. It was found that students' ranking on usefulness of the course modules varied over the year. The majority of students (approximately 70%) perceived the individual modules to be very useful and critical for their learning. This could be attributed to heterogeneous group of students in the class each year with diverse learning styles and pre-existing knowledge. Overall, students' perception about the course and its relevance rating were in the neutral, agree and strong agree categories. To get a better understanding of the students' perceptions about the course, future work will involve conducting focus groups discussion as a supplemental tool along with end of the semester survey. A pre-test was also administered at the beginning of the semester in Fall 2014 to understand students foundational knowledge about sustainability. The difficulty level of the pre-test questions was found to be low and so the pre-test needs further refinement. Students' inability to answer some of the basic questions and unfamiliarity with some of the terms used in a module will be addressed in the lectures. In the future, attempts will be made to go beyond testing basic understanding of students and developing set of questions with better distribution of difficulty and easiness and that are not too specific. In addition, input from the subject matter experts will be taken to finalize the test questions.

Acknowledgements

We gratefully acknowledge Dr. Sara B. Marcketti, Associate Director, Center for Excellence in Learning and Teaching, Iowa State University, for her valuable suggestions and Ian Corbin, Graduate Teaching Assistant, for his help with data collection. The work was supported as part of the CenUSA project funded by Agriculture and Food Research Initiative Competitive Grant No. 2011-68005-30411 from the National Institute of Food and Agriculture; and Teaching as Research proposal funded by the Center for Excellence in Learning and Teaching, Iowa State University.

Bibliogrpahy

1. Filho, W. L., *Teaching sustainability at universities: Towards curriculum greening.* Peter Lang Publishing Group: **2002**; Vol. 11.
2. Zwickle, A.; Koontz, M. T.; Slagle, M. K.; Bruskotter, J. T., Assessing sustainability knowledge of a student population: developing a tool to measure knowledge in the environmental, economic, and social domains. *The Associaltion Of The Advancement Of Sustianability In Higher Education.* **2013**, 1-25.
3. Boyle, C., Considerations on educating enginners in sustainability. *International Journal of Sustianability In Higher Education.* **2004,** *5* (2), 147-155.
4. Glavič, P., Sustainability engineering education. *Clean Technologies and Environmental Policy.* **2006,** *8* (1), 24-30.
5. Newton, R. Pre and Post Testing. http://www.icbl.hw.ac.uk/ltdi/cookbook/info_pre_and_post/index.html#endhead (Accessed: 9 September, **2014**).
6. I-TECH, Guidelines for pre- and post-testing. University of Washington: Seattle, Washington,USA, 2008; Vol. **2014**.
7. Krueger, R. A.; Casey, M. A., *Focus Groups : A Practical Guide for Applied Research Fourth Edition* SAGE Publications, Inc., Thousands Oaks, CA, 2009.
8. David L. Morgan; Richard A. Krueger, *The Focus Group Kit*. SAGE Publications, Inc., Thousands Oaks, CA, **1998**; Vol. 1-6.
9. Weight, P. S.; Hendershott, A., Using focus groups to obatian students perceptions of genereal education. *To Improve The Academy.* **1992,** *11*, 87-104.
10. Wolff, B.; Knodel, J.; Sittitrai, W., *Successful Focus Groups Advancing the State of the Art Focus groups and survey as complementary reserch methods: A case example*. SAGE Publications, Inc., **1993**.
11. Maloney, D. P.; O'Kuma, T. L.; Hieggelke, C. J.; Heuvelen, A. V., Surveying students' conceptual knowledge of electricity and magnetism *American Journal of Physics.* **2001,** *69*, S12-S23.