122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Paper ID #11985

ESTABLISHING SUSTAINABILITY COMPONENT IN AN ENGINEERING DESIGN COURSE

Dr. Jaby Mohammed, The Petroleum Institute

Jaby Mohammed is a faculty at The Petroleum Institute, Abu Dhabi, UAE. He received his PhD in Industrial Engineering from University of Louisville (2006), masters in Industrial Engineering from University of Louisville (2003) and also a master's in business administration from Indira Gandhi National Open University (2001). His research interests include advanced manufacturing, design methodologies, six sigma, lean manufacturing, and engineering education. He previously taught at Indiana Purdue Fort Wayne, IN and at Morehead State University, KY. He is a member of IIE, SME, ASQ, ASEE, and Informs.

Dr. Sami Ainane, Petroleum Institute

©American Society for Engineering Education, 2015

ESTABLISHING SUSTAINABILITY COMPONENT IN AN ENGINEERING DESIGN COURSE

Environmental protection agency defines sustainability as something that creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations. The concept of sustainability has been widely accepted and is considered a desirable feature in any product or system that is being designed. Engineers play a vital role in the societal development and even they are characterized as the exploiters of potential for useful purpose. Perceptions on sustainability differ from culture to culture and from industry to industry.

The concept of sustainability is usually introduced to students by mean of the University culture or by means of different introductory engineering courses. Most of the engineering programs have an introductory engineering design courses, where the sustainability module is placed. STPS 201 (Strategies for team based problem solving) is a three credit sophomore engineering design course at The Petroleum Institute which introduces the students to engineering design. This course is currently being looked to address the sustainability component which would serve to increase the awareness of sustainability, thereby fulfilling the ABET requirements for the program, objectives of the university sponsors, and finally the UAE 2020 vision. The objectives and visions are laid very clearly at the top but not much is done between the different levels to address the sustainability component. So a "bottom-up" approach is being used to embed the sustainability into the university curricula to meet the objectives and vision.

In this paper, authors will address

- Need to address the sustainability component in the curriculum
- Student perceptions and knowledge on sustainability by means of a survey before taking the course.

Keywords: Sustainability, Engineering design and manufacturing

Introduction

Sustainability is an important issue for any organization in the twenty first century and have become an integral part of the engineering practices and policies. As most of the organization goes through this green revolution most of the companies and corporations have adopted the cradle to cradle design, which is a regenerative design and manufacturing approach, to provide a holistic system for corporate responsibility.

In today's industrial environment, sustainability is one of the key objectives that companies are striving toward, the key component of this process is to incorporate sustainability to the corporate structure. The earth summit in Rio de Janeiro was the first global conference on

sustainability which was trying to make the Governments rethink economic development and find ways to halt the destruction of irreplaceable natural resources and pollution of the planet [4]. The main outcome of this conference was to transform the behaviors and attitudes that would bring the necessary changes for a healthier planet. Brundtland Commissions also report similar facts to make the planet greener. One of the ways to change the attitude and behavior was to educate the people; with this in place many accreditation bodies built the curriculum emphasizing the sustainability component [4]. To this end large scale of academic embedding of sustainability component have started to occur at different levels. Ilo and Boyle also had a very similar approach of introducing the concept to the curriculum [8, 10].

Background

The mission of the Petroleum Institute is to impart world-class education in engineering and applied sciences in order to support and advance the petroleum and energy industries. The Institute strives to develop students as whole persons and as the future leaders in their respective fields of expertise in the UAE and globally. ADNOC the sponsor company of The Petroleum Institute has taken serious steps to fulfill their commitment towards sustainability. A set of business strategies and programs are implemented, monitored closely to meet the needs of the stake holder. Achieving sustainability within the oil and gas industry is not an easy thing and does require considerable amount, time, effort, and education to enhance ADNOC's environmental and social performance. Reducing gas flaring, greenhouse gas emissions, and introducing new technologies for producing cleaner fuels are some of the activities that ADNOC had been involved in past few years. The company also has supported and sponsored various social, educational, and cultural activities and also want its educational institutional organization to follow its footsteps. With this in place, one of the goals of the graduating student from PI is to appreciate his/her role to sustainability and how one could apply the same to his future work place.

Course frame work

The Petroleum Institute (PI) was created in 2001 with the goal of establishing itself as an international institution in tertiary engineering education and research in areas of significance to the oil and gas and the broader energy industries. Currently the PI offers Bachelor degrees in Chemical, Electrical, Mechanical, Petroleum Engineering, and Petroleum Geosciences. The students after they go through the high school are admitted based on their TOEFL score and the GPA in high school. Most of the students go through a foundation program before they are enrolled as a freshmen student in PI. The foundation program is designed to help students develop knowledge, study skills, technical, analytical, and communication skills which are necessary to meet the PI's entrance requirements and assist them in their future studies at the Petroleum Institute. The foundation program at the PI is called as the Academic Bridge program.

Once the student reaches the freshmen level there are core courses that have to complete irrespective of their majors. The core course are offered through the Arts and Science Program and some elective courses required for the engineering programs are also offered through Arts and Science. The six departments within the Arts and Science department include Mathematics, Physics, Chemistry, Humanities and Social Sciences, Communication, and General Studies. Students must take these required courses in a sequence.

The general studies department offers a sequence of three courses. In the freshmen year students take, the introduction to petroleum engineering in the petroleum industry followed by two sophomore design courses called STEPS, which stands for Strategies for Team-based Engineering Problem Solving. In STEPS courses students integrate what they are learning in science, mathematics and communications, couple it with teamwork and project management tools and build a working prototype of a useful machine. The requirement to start the STEPS courses is that they should complete the first course of Physics and two levels of communication class. After successful completion of the courses in Arts & Sciences, students enter one of the six engineering departments to do upper level courses and pursue a specialized engineering degree program.

Sustainability at PI

Currently at the Petroleum Institute, the modules of sustainability is introduced at different levels as a standalone elective subject / entity. There are potential danger of teaching these components as a standalone activity. One of the potential problem is the educational disconnect that can happen with the curriculum. Repetition of the same material from freshmen to senior level could happen, which results in the waste of time and resource. In light of this it is important that new frame works (like integrative learning) and methodologies and are needed for successful implementation of the sustainability component into the curriculum. Augsburg, T., & De Barros in their paper discusses how they were able to transform a long standing course to an interdisciplinary and an integrative course by introducing a core course and having smaller modules within the curriculum. In integrative learning knowledge and skills are connected from multiple sources and they are applied at different setting using different views [1, 11, 12]. The main idea is to incorporate it as integrated studies that would involve making connections within a between fields major, between curriculum, and multi-disciplinary curriculum [1, 2].

Before introducing the sustainability component to the curriculum, it is important to understand the student perception and knowledge of sustainability. In this paper authors would discuss about the finding of The Petroleum Institute's student perception and knowledge. Sustainable development meets the needs of the present without compromising the ability of the future generations to meet their own needs. The overall goal is to integrate the values in sustainable development into all aspects of learning to the curriculum. The initial survey to the students will lay the foundations for the development of the curriculum by knowing students' knowledge, attitudes, and behaviors concerning sustainability.

Participants / Questionnaire

The present study was conducted with hundred students in an engineering design course (STEPS 201) at the Petroleum Institute in Abu Dhabi. The class consisted of sophomores students in both Men's and Women's campus.

With the increasing emphasis given on sustainability and to do it across the curriculum, it is important to assess the knowledge of sustainability with the students. The first task was to develop an assessment tool to measure the knowledge of the students. Multiple choice questions was used to measure knowledge of a concept. Questions involved integrative concepts to assess multiple learning and application.

A three page questionnaire was developed that contained a set of 18 questions testing student's perceptions and knowledge of sustainability. The survey was created based on the study done and tools used by the Association for the Advancement of Sustainability in Higher Education [3, 4, 5, 7, and 9].

Most of the questions was directly involved with checking students' knowledge and few questions was of Likert-type items from strongly disagree (1) to strongly agree (5). Assessment of Sustainability Knowledge and perception is given below. The percentages indicate results from the design engineering students from The Petroleum Institute.

Sustainability Knowledge and Perception survey

1. Why is it important to recycle? (Choose all that apply)
    a) Recycling decreases the amount of habitat lost due to resource extraction. **(30%)**
    b) Recycling typically takes less energy to process recycled materials than to use new materials. **(35%)**
    c) Recycling cuts down on the amount of trash that goes into landfills. **(35%)**
    d) None of these (recycling is not an efficient way of dealing with our wastes.) **(0%)**

2. What are the potential effects of global climate change? (Choose all that apply)
    a) Loss of habitats **(22%)**
    b) Less severe weather **(28%)**
    c) Expansion of deserts **(34%)**
    d) Decrease in sea level **(15%)**

3. Imagine you are one of many fishermen who rely on the fish you catch from the Arabian sea as your main source of income. The Fishermen Council determined that each fisherman must

limit his/her catch to 5 tons per year to maintain the fishery. You decide to catch 6 tons of fish this year. What could be the results of your decision? (Choose all that apply)

a) You make more money this year than you would have if you caught 5 tons of fish. **(19%)**

b) You make less money this year than you would have if you caught 5 tons of fish. **(33%)**

c) The total number of fish that are available to catch each year could decrease. **(29%)**

d) Fishermen, including you, could go out of business **(19%)**

4. The most significant driver in the loss of species and ecosystems around the world is

a) overhunting/overharvesting **(22%)**

b) Conversion of natural space into human developments (farmland, cities, etc.) **(33%)**

c) Acid rain **(33%)**

d) Breeding of animals in zoos **(12%)**

6. Which of the following is an example of environmental justice?

a) Urban citizens win a bill to have toxic wastes taken to rural communities. **(23.5%)**

b) Government dams a river, flooding Native American tribal lands, to create hydro-power for large cities. **(29.4%)**

c) Indigenous communities are involved in setting a quota for the amount of wood that they can take from a protected forest next to their village. **(41%)**

d) Corporations build factories in developing countries where environmental laws are less strict. **(5%)**

7. Of the following, which contributes the most to sustainability?

a) Recycling products **(33%)**

b) Reusing products **(28%)**

c) Buying the newest products to increase economic development **(16%)**

d) Reducing consumption of products **(23%)**

8. What factors influence human population's impact on Earth's resources? (Choose all that apply.)

a) Size of the population **(41%)**

b) Amount of materials used per person **(41%)**

c) Use of technology that lessens our impact **(18%)**

9. Using non-renewable resources, like fossil fuels, can create economic growth but future generations will be disadvantaged if the current generation overuses these resources. Which of

the following principles can we follow if we do not want to disadvantage the next generation? (Choose all that apply)

a) Renewable resources such as fish, soil, and groundwater must be used no faster than the rate at which they regenerate. **(20%)**

b) Nonrenewable resources such as minerals and fossil fuels must be used no faster than renewable substitutes for them can be put into place. **(24%)**

c) Pollution and wastes must be emitted no faster than natural systems can absorb them, recycle them, or render them harmless. **(50%)**

d) None (Humans will never run out of non-renewable resources.) **(16%)**

10. Which of the following statements about water is/are true? (Choose all that apply)

a) The number of people who have access to clean drinking water will increase over the next two decades **(30%)**

b) Globally, freshwater reserves (aquifers) are used faster than they are replenished. **(30%)**

c) Many people around the world do not have access to clean drinking water, so their only option is to drink contaminated water. **(35%)**

d) Global warming does not threaten to decrease freshwater reserves. **(5%)**

11. Imagine that we had to pay for all the costs associated with the manufacturing of the goods we use every day. What would go into calculating the true costs of a product? (Choose all that apply)

a) The cost of raw materials to make the product **(21%)**

b) The cost of environmental damage caused by production **(33%)**

c) The cost to transport that product from its manufacturing location to your location **(26%)**

d) The cost of health care for employees who manufacture the product **(20%)**

12. Put the following list in order of the activities with the largest environmental impact to those with the smallest environmental impact

A. Keeping a cell phone charger plugged into an electrical outlet for 12 hours

B. Producing one McDonalds quarter-pound hamburger

C. Producing one McDonalds chicken sandwich

D. Flying in a commercial airplane from Washington DC to China

a) A, C, B, D **(50%)**

b) D, A, B, C **(28%)**

c) D, C, B, A **(11%)**

d) D, B, C, A **(11%)**

13. How involved are you with sustainability or sustainable technologies?

a) Fully involved **(6%)**
b) Somewhat Involved **(77%)**
c) Uninvolved **(7%)**

14. Which of the following sustainable segments do you consider to be the two most important?

a) Designs that use less energy or reduce emissions **(21%)**
b) Designs that comply with Environmental Standards and Regulations **(3%)**
c) Designs that use renewable/recyclable/recycled materials **(15%)**
d) Designs that reduce material usage or waste in manufacturing **(18%)**
e) Designs with non-toxic materials **(6%)**
f) Designs with low carbon footprints **(12%)**
g) Manufacturing processes that use less energy and natural resources **(15%)**
h) Manufacturing processes that produce less pollution **(0%)**
i) Manufacturing processes that minimize the usage or production of substances of concern **(0%)**
j) Products that can be disposed of safely, including biodegradable materials and packaging **(6%)**
k) Products that require less packaging **(3%)**

15. To what extent do you agree or disagree with each of the following statements about the use of sustainable and/or green design principles in the design, production, and operation of manufactured products?

a) Incorporating sustainable and/or green design practices is too complex for my educational institution **(18.8%)**
b) My school has a sustainable design class, program, or assignment **(23.8%)**
c) Designing sustainable and/or green products results in more product innovation **(42.2%)**
d) Projects that follow sustainable and/or green design principles typically have higher design costs **(9.4%)**
e) The people I study with are increasingly interested in sustainable and/or green design principles in mechanical systems **(4.7%)**

16. How does your school provide opportunities for learning about sustainable design principles and/or technologies? (Check all that apply.)

a) It doesn't **(8%)**
b) Extracurricular projects and/or competitions **(24%)**
c) Whole major / minors devoted to sustainable Engineering **(20%)**
d) Special assignments on sustainable engineering **(40%)**
e) Special elective classes on sustainable design **(20%)**
f) Sustainability is included in the standard curriculum **(16%)**

17. Outside of your engineering studies, how interested are you personally in green and sustainable information and causes?

a) Extremely interested **(21%)**
b) Somewhat Interested **(36.8%)**
c) Neutral **(26.3%)**
d) Not very interested **(10.5%)**
e) Not at all interested **(5.3%)**

18. What is the primary motivation for your interest in green and sustainable information and causes?

a) It sounds like an interesting topic to learn more about **(11%)**
b) It will give me a competitive advantage when applying for jobs **(50%)**
c) It is necessary in my career as an engineer **(16.7%)**
d) I want to do well in the world **(16.7%)**
e) Others, please describe **(5.6%)**

Results and Discussion

In general, the assessment results does not show a pattern in majority of the questions. The environmental indicator questions, economic indicator questions, and social questions were not found to be skewed in any direction, which shows that there is not much clarity on the student perception and knowledge of sustainability. Which strongly suggests the need for students to go through a framework within the curriculum to understand and apply the concept. This also suggests that it may be desirable to develop measuring indicators also through the curriculum. In perception, sustainability does remain as the buzzword for the current generation and they would use the same for having a competitive advantage while applying for jobs.

Increasing sustainability knowledge among students is a common goal of colleges and universities. The STEPS course is a multi-disciplinary course with respect to the course content and would a great place to introduce the concept which the students could carry forward through the design spine. Overall, students' perception about sustainability was neutral and above. To get a better understanding of the students' perceptions about the course, future work will involve conducting focus groups discussion as a supplemental tool.

References

1. Augsburg, T., & de Barros, J. A. (2010, June). Integrating different modes of inquiry for pre-service teachers. In Proceedings of the first interdisciplinary CHESS Interactions Conference

2. Association for the Advancement of Sustainability in Higher Education (2012), "Version 1.2 Technical Manual: February 2012", available at: http://www.aashe.org/files/documents/STARS/stars_1.2_technical_manual.pdf (accessed 24 January 2013).

3. Benn, S. and Dunphy, D. (2009), "Action research as an approach to integrating sustainability in MBA programs: an exploratory study", Journal of Management Education, Vol. 33 No. 3, pp. 276-95. 23

4. Brundtland Commission, (1987) Our Common Future, The Report of the World Commission on Environment and Development, Oxford University Press, Oxford.

5. Crocker, L. M. and Algina, J. (1986), Introduction to classical and modern test theory. Holt Rinehart & Winston, New York, New York.

6. DeVellis, R. F. (2003), Scale Development: Theory and Applications, 2nd edition, volume 26, Sage, Thousand Oaks, California.

7. Dillman, D. A., Smyth, J. D., Christian, L. M, (2009), Internet, mail, and mixed-mode surveys: the tailored design method. Hoboken, N.J., Wiley & Sons.

8. lho, W. L., Teaching sustainability at universities: Towards curriculum greening. Peter Lang Publishing Group: 2002; Vol. 11. 2.

9. 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 Sustainability in Higher Education. 2013, 1-25. 3.

10. Boyle, C., Considerations on educating engineers in sustainability. International Journal of Sustainability in Higher Education. 2004, 5 (2), 147-155. 4.

11. Glavič, P., Sustainability engineering education. Clean Technologies and Environmental Policy. 2006, 8 (1), 24-30. 5.

12. 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