INTEGRATING STUDY ABROAD EXPERIENCE WITH TEACHING SUSTAINABILITY COURSE IN AFRICA

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Abstract
The environment has some capacity to cope with the impact from all human activities so that a certain level of impact can be absorbed without lasting damage. However, studies show that current human activities exceed this threshold with increasing frequency, diminishing the quality of the world in which we now live and threatening the well-being of future generations. Part of this impact derives from the manufacture, use, and disposal of products which are made from materials.

This paper presents a method of teaching and exploring sustainability within the materials, manufacturing, and design context by highlighting a study abroad course that was taught during the 2011 May term. The program was led by Professors from University of Minnesota Duluth (UMD), USA and Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana. It exposed students to global concepts of sustainability with emphasis on alternative materials and manufacturing methods in Ghana. Learning was reinforced by visits to local manufacturing facilities, art centers, museums, and historical villages. Also, students were engaged in cultural activities including: learning Akan language, dancing, keyboarding, textile dying, and basketeering as part of their study abroad experience in Ghana. During the program, students were given projects to analyze, evaluate, and make recommendations on how to improve on the sustainability aspects of a product. The major sustainability measures considered are embodied energy and carbon dioxide (CO_2) footprints and the projects conducted were on bamboo bicycle frame; non-chemical water filter; and production of kente cloth. Students' learning was assessed with written report, project presentation, and diary of tours/cultural activities linked to sustainability.

Keywords: Sustainability, Embodied Energy, Eco-audit, Environmental Impact, and Study Abroad

I. Background

UMD and KNUST have agreed to establish collaboration in teaching, study abroad experience, and research between the two universities. A three-credit sustainability course is designed for junior and senior level Mechanical, Industrial and other Engineering major students in the College. This course is taught as a short term study abroad program consisting of two and half hours of lecture and several hours of field trips at KNUST, Kumasi, Ghana, West Africa. The UMD College of Science and Engineering is a predominantly four-year ABET accredited engineering school offering

engineering degrees in Mechanical & Industrial, Chemical, Computer Science, Civil and Electrical & Computer Engineering. The College of Engineering at KNUST comprises of four Faculties and two Research Centers. The Faculties include the Faculty of Chemical and Materials; Civil and Geometric Engineering; Electrical and Computer; and Mechanical and Agricultural Engineering. Their Technology Consultancy Center (TCC) and Energy Center are the main research wings of college. KNUST has several programs that focus on use of local materials and processes for making eco-informed products including non-chemical clay water filter developed by TCC; and bamboo frame project by Materials Engineering.

II. Objectives of the Course

It is hopeful that upon completing this program, the students will be able to perform the following tasks: (1) Analyze and describe any materials' life cycle; (2) Conduct eco-audits using CES EduPack eco-audit tool; (3) Analyze eco-data: values, sources, precision; (4) Design an eco-informed product; (5) Relate legislation with sustainability; (6) Write report on a sustainability project; and (7) Make oral presentation on sustainability project and Ghana trip experience.

Objective one is achieved through lectures and case studies on life cycle of products and International Standard Organization (ISO) 14000. Objectives two through four are achieved through lectures and completing group projects on sustainability. During the program, students will use EduPack Software, Granta Design[2] to facilitate learning and implementation of projects. Objectives five through seven are achieved through report and oral presentation. Students are required to prepare their reports in an engineering technical paper format and the presentations are made in two parts: first part on results of project and the second part on Ghana trip experience.

III. Description of Course

The course has three major components: lecture; projects/cultural activities/tours; and report/presentation as illustrated in Figure 1. Each of the components is described in the following paragraphs.

Lecture. The lectures are used to educate students on topics related to sustainability including: material resources; consumption; depletion; environment emissions; life cycle assessment (LCA); and recycle. An approach that the lecture emphasizes is the principles guiding a simple and rapid strategy for implementing eco-informed decisions at the design stage of product development. Developed by Ashby[1], the approach has three major components: Adoption of simple metrics of environmental stress; Distinction of the four phases of life; and Formulation of design objectives based on the energy or carbon breakdown of the phases of life. However, before this strategy is introduced and implemented in the lecture, the students learn the details and difficulties of full Life Cycle Assessment (LCA). The standards for conducting an LCA, issued by the International Standards Organization (ISO 14040 and its subsections 14041, 14042, and 14043) are studied in full, stressing the difficulties of interpreting the aggregate measures (eco-indicators) by an engineer at the design stage of product development. Further, the students learn streamlined LCA as an alternative strategy to simplify the complexity of a full LCA study; this method of assessment focuses on the most significant inputs, neglecting those perceived to be secondary. Figure 2 illustrates a typical material life cycle that was studied, where an ore is mined and processed to produce a usable material, which is then transformed into a more useful product via manufacturing processes. At the end of useful life of the product, it is disposed, recycled, or refurbished and reused. An important outcome from learning LCA is that students understand that at each stage of life of a product, energy and materials are consumed and emissions are generated that include:

waste heat and solid, liquid, and gaseous emissions. Students are able to evaluate energy or CO_2 footprint as the logical choices for measuring environmental impact because they are related and are understood by the public at large.

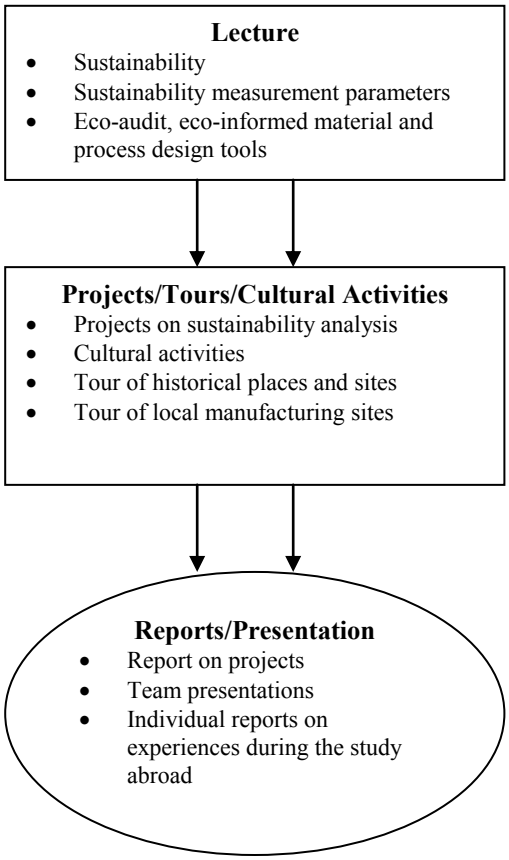

Figure 1 Components of the study abroad program

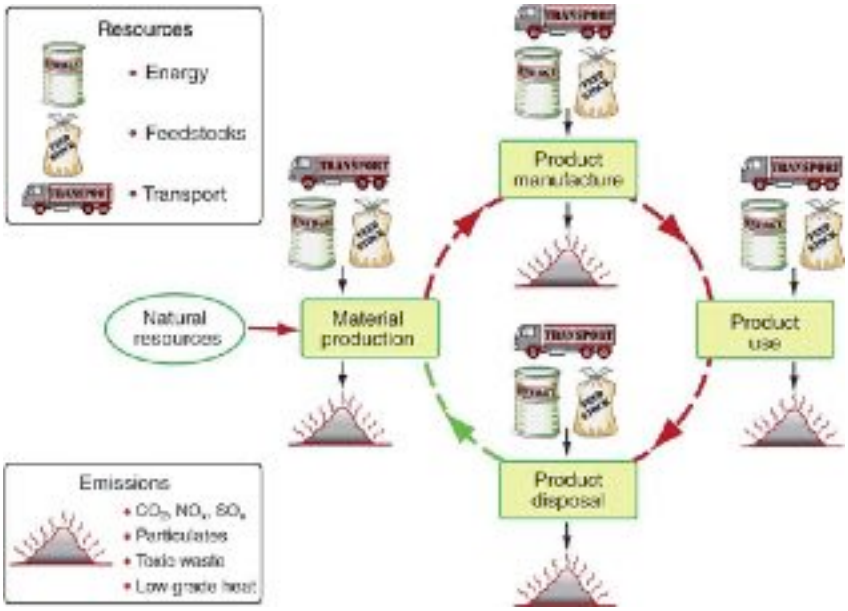

Figure 2 The material life cycle showing consumption of energy and materials and emission of waste heat, solid, liquid, and gaseous emissions. (Ashby, 2009)

Projects, Tours and Cultural Activities. Three groups consisting of three students in each are formed and assigned to work on three different sustainability projects. The projects are defined with opportunities to analyze the sustainability of locally made products and conduct comparative analysis with non-locally made similar products. The results from the sustainability analysis are then used to make eco-informed decisions about actions that should be implemented to reduce environmental stress of the products studied. Figures 3 illustrate the three projects which are titled as follows: sustainability evaluation of kente cloth production process; sustainability analysis and evaluation of a bamboo bicycle frame; and sustainability evaluation of locally manufactured non-chemical clay water filter. These projects are briefly described in the following paragraphs.

3.1 Kente textile production

3.2 Bamboo bicycle frame

3.3 Non-chemical Clay water filter

Figure 3 Three projects on sustainability

Sustainability Evaluation of Locally Manufactured Non-chemical Clay Water Filter. The Applied Industrial Ceramics Center of KNUST has developed and manufactured a non-chemical water filter

from clay material to be distributed to the rural villages for filtering drinking water. This will have great impact on the lives of people living in areas where water filtering is normally avoided due to unavailability of an affordable and functional water filter. The materials used in the design and manufacture of the water filter are classified as renewable because they are natural and can be recycled. Amongst the five major components of the water filter, two are imported from China; two are transported from Accra, Ghana; and the filter unit is made locally with clay at KNUST. Figure 4 is a picture to illustrate the components of the water filter unit. The manufacturing processes involved in making the filter include: clay molding; slip casting; firing; and sintering. The objectives of this project include: to analyze and evaluate the sustainability and economics of this product; compare the results to similar type of filter but made with nonrenewable materials; and make recommendations that will focus at making the non-chemical clay water filter more eco friendly.

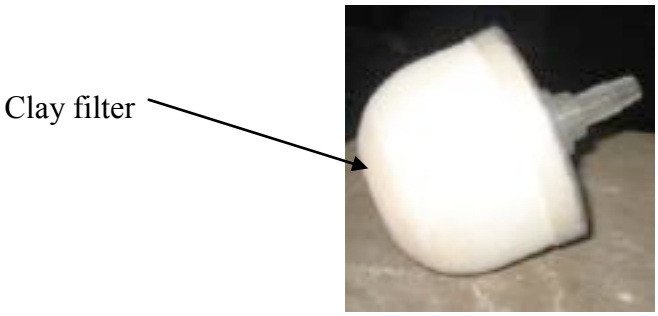

Figure 4 Assembly of the clay water filter

Sustainability Evaluation of Kente Textile Production Process. Kente weaving was developed in the 17th Century A.D. by the Ashanti people from the town of Bonwire; now the leading Kente weaving center in Ashanti, Ghana. Kente was adopted as a royal cloth and is produced as a cloth of prestige reserved for special occasions. The weaving apparatus are hand made by weavers themselves or by others who are specialized in equipment making. The loom is one such apparatus that is constructed with wood; a set of two, four or six heddles attached to treadles with pulleys and spools inserted in them; shuttels with bobbins inserted in them, and sword stick. Yarns are from factory made cotton, silk or spun rayon from factories in Ghana and outside Ghana. It takes an average of four weeks to weave 10 yards of kente with triple layer design; triple layer is more complicated than single layer weaving. Loom process is considered renewable as it is made with wood and does not use fossil fuel as illustrated in Figure 5. The objectives of this project include: to analyze and evaluate the sustainability and economics of kente production process; to compare the results to similar kente cloth made by printing; and to recommend solutions to improving the sustainability of the product.

Figure 5 Manufacturing of kente cloth with loom apparatus

Sustainability Analysis and Evaluation of Bamboo Bicycle Frame. Youngso project, Apaah, Ghana is manufacturing bicycle frames with bamboo materials. The rest of the bicycle systems are built and assembled similar to our conventional bicycle design. The bamboo material is harvested, treated and inspected before using it as a building material. Once the frame is completed, it is shipped to final destinations of use in the rural areas and sometimes to North America and Asia. Currently, there is a 10 year warranty on a bamboo bicycle frame. Figure 3.2 is a picture to illustrate a finished bamboo bicycle frame. Similar to the other two projects, the objectives of this project include: assessment and evaluation of the sustainability of a bicycle frame built with bamboo material; comparison of bamboo bicycle frame to aluminum and fiber glass reinforced composite frames; and recommendation of solutions to reduce the environmental stress of bamboo bicycle frame. In addition, comparative engineering analyses of the three frame materials are conducted using SolidWorks software.

Cultural Activities and Tours. Cultural activities including: learning of Akan language; dancing; drumming; textile dying; and weaving are integrated with the program to give students cultural education about Ghana. In addition, several historical places; manufacturing centers; African art museums; historical villages; and centers of attraction are visited to give students study abroad experience. During these tours and cultural activities, students are expected to keep a diary about their experience including how they impact global sustainability.

Writing and Presentation. In the writing component of the program, each group is expected to prepare a detailed report with an engineering journal format describing the project objectives, procedures, results, analysis, and conclusions. Literature survey is conducted by the students to support their background knowledge on the materials, physical properties and current research that have been done on the respective project. On the data analysis and results sections of the report, students are expected to compute and demonstrate the following analysis: (1) Computation and description of embodied energy of the products' components; (2) Computation and description of CO_2 footprint of the products; (3) Identification and description of opportunity to improve sustainability of the product; and (4) Evaluation of economics and recommendation of solutions to improve the sustainability of the product.

IV. Discussion

This approach of teaching sustainability bridges the gap between theory and practical experience that many students encounter in many engineering programs. The study abroad program in Ghana is a whole life experience for the students about Africa and understanding of sustainability from a global perspective. The scopes of the projects are designed to be completed in two weeks and give students the practical skill of designing eco-informed products. The project teams are formed to have both multicultural and multidisciplinary characteristics; as a result, providing opportunities for the students to learn engineering from varying perspectives. There are advantages and disadvantages associated with this approach of delivering education to students as follows: (1) Teaching sustainability course in Africa provides the students an opportunity to learn and understand sustainability from global perspective; (2) Integration with cultural activities and tours provides the students with better education about how Africans live with specific emphasis on Ghana; (3) The projects conducted facilitate students' understanding and retention of course material on sustainability; (4) Students develop critical thinking skills as they are challenged to provide and describe solutions to improve sustainability of a product at a design stage; (5) Students become familiar with writing conventions of engineering journals; and (6) Students learn to work and write in multicultural and multidisciplinary teams.

Few of the disadvantages that may be associated with this approach of learning are: (1) The cost of completing the three credits course is higher than a normal three credit course taken at home; and (2) Increased faculty and student time is required daily to accommodate the cultural activities; tours; projects; evaluation of reports; and presentations.

V. Assessment of Course

Students' Assessment. Students are assessed on the three areas of the course: lecture/project; report/presentation; and cultural activities/tours. Students' participation on the project is evaluated by faculty observation, as well as students' team evaluation. Their reports and presentations are assessed as a team and as an individual respectively. Their experience from the cultural activities and tours are evaluated from the journal they have kept about the sustainability aspects of these activities.

Course Evaluation. One of the primary reasons of the course evaluation is to find out how the students feel about some of the activities that were included in the program; what should be removed or retained if the course is to be taught again. An evaluation was conducted by KNUST and another was conducted after the students have returned home by UMD. The students have provided positive feedback to this learning approach and have shown to have deeper retention of the subject. All the students expressed that they hold different opinion about Africans and how they live. They expressed that the cultural activities and tours were the best part of the program and should be continued. They liked the multicultural and multidisciplinary nature of the teams because it provided opportunity for them to exchange both cultural and political knowledge about USA and Ghana. However, they expressed that the time was not enough for them to prepare detailed report that was expected from them. Finally, they expressed that integration of an eco-audit and material selection software in the program was very valuable and should be continued with a level three version of the software.

References

[1] Ashby, M. F. (2009), Materials and the Environment: Eco-Informed Material Choice, Elsevier, Butterwork-Heinemann Publications.
[2] Granta Design Ltd (2011), EduPack Software, University of Cambridge.

Biography

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