Board 128: Work in Progress: Integrating Sustainability Engineering Education and Design into the K-12 Classroom: A Case Study in Electronics Recycling for Middle-School Youth

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Abstract

Engineers today consider how to advance technologies with limited natural resources to achieve a sustainable future. Sustainability has been integrated into a variety of engineering curricula where educators face challenges of the misconception perceived by students that technology can offer complete solutions to sustainability. In this study, a constructive educational module of sustainability was integrated into a K-12 industry-oriented curriculum at a public middle school as a practice to introduce the societal, economic, and environmental mindsets to pre-college students with reduced technological content. Data collected are instructor's reflections for the module that lead to a summative critique of the outcomes and improvements. This study provides the engineering education community the evidence that middle-school youth can well perceive sustainability framework and the insights for researchers who are looking to integrate sustainable engineering to pre-collegiate engineering settings.

Keywords

curriculum integration, K-12, sustainability, course design, societal awareness

Introduction

Our next-generation engineers must be able to design technological activities with restricted natural resources for wider applications, sustaining the environment and protecting human health for future generations [1]-[2]. Sustainability is traditionally covered by civil engineering [3]-[4], environmental engineering [5], and chemical engineering [6] and is now extended to a broader discipline, e.g., software engineering [7]. Scholars have identified the three pillars of sustainability as environmental, economical, and societal, making it a multidisciplinary subject [8]. Many universities have also integrated sustainability content into current engineering education to cultivate students who can deal with the societal and economic perspectives associated with technology advancement [9]-[10]. Emerging challenges of sustainability education include the misconception resulted from the ignorance of societal and economic effects [11]-[12], insufficient resources and training for educators, and lack of motivations for students to participate in sustainability-related activities [13].

To address those challenges, previous studies reported that a community-oriented approach with more constructive but less technological activities can not only enhance students' knowledge of sustainability [11] but also trigger students' interests in sustainability [14]. Therefore, K-12 classroom becomes a favorable place to implement practices of integrating sustainability with the purpose of increasing precollege children's awareness and motivations and preventing misconceptions with a constructively designed curriculum. A real-life implementation of curriculum integration of sustainability in the K-12 setting plays a key role in validating and evaluating the feasibility of this approach. In this study, a module of sustainability was designed for 12 one-hour sessions over 3 months with a focus on the recycling of electronics and was implemented in an industrial-oriented class. We use instructor reflections to provide preliminary insights for addressing difficulties associated with sustainability education, i.e., whether middle school youth can relate the societal and economic aspects to the sustainability concept.

Purpose of Study
The purpose of the study is to reformulate a college-level curriculum on global sustainability project into a module that would be suitable for middle school students. The lessons focus on electronics waste (e-waste) that falls under the category of sustainability. The goal of the module is to increase students' awareness of living a sustainable lifestyle and become familiar with the enduring concepts of the three pillars of sustainability, i.e., environment, economy, and society. The research team includes graduate students and faculty from the departments of environmental engineering, materials engineering, and engineering education, reflecting the multidisciplinary nature of sustainability education.

Project Design
We design the sustainability module for an industry-orientated course at a public middle school in a Midwestern city. The students in this class are enrolled in 7th and 8th grade. It requires an understanding of the students' preference and responses on various learning topics to bridge the gap between the college and K-12 classroom. A graduate student with an interdisciplinary traineeship on global sustainability served as the primary instructor for the course, with the support of the host teacher. The schedule for the visiting instructor is: (1) in week 1-2, the instructor observes the class and accepts training on K-12 education; (2) during week 3-6, the instructor assists the host teacher during the course and develop a lesson plan; (3) in week 7-9, the instructor teaches the designed module and collects reflections from the students; (4) Post-project, the instructor evaluates and reflects on students' participation and outcomes.

The focus of this industry-orientated course is to introduce middle school students the engineering design concepts with hands-on projects such as creating a bridge using straws and making wooden car models. Each student will learn to use tools such as the Autodesk software and the mechanical cutting machine. Each week students will be introduced to a new project by the instructor and divided into teams where they will collaborate to design real world products.

Lesson Plan
<u>Students will be able to</u>
- Recognize everyday electronic products and how electronics relate to our daily lives
- Dissemble a hard drive and be familiar with recyclable materials such as gold and copper
- Outline relevant reasons why people tend not to recycle electronic wastes
- Reflect on the social responsibility of different individuals

<u>Session 1: Name it! "Electronic devices"</u>
In this activity, the class was divided into two different groups, A and B. Each group would be asked to name an electronic device within five seconds (every group member may answer) and the instructor would record each item under the group list (A and B) in PowerPoint. For example, the instructor would type "laptops" under list A if group A mentioned it. The game stopped whenever one of the groups failed to name an electronic device within five seconds and the other group won. The purpose of this activity was to help students recognize how many electronics were used and electronic wastes were produced in daily lives.

<u>Session 2 — Dissembling a hard drive</u>

Students were set to teams with a capacity of two and each team was provided with a hard drive repair kit along with a wasted hard drive. Each team disassembled their hard-drive and inventoried components into organizing containers. The purpose of this activity was for students to familiarize themselves with the components inside a hard-drive and to understand the challenges in hard drive recycling industry.

Session 3 — Electronics junk drawer

Each student was required to make a two-page PowerPoint slideshow. On the first page, students would take two photographs of an e-waste "junk drawer" (actual drawer, closet shelf, bin or any other container/location where they keep electronic devices that were no longer in use) at their home. On the second page, students were required to discuss with people they live with about the following two questions and write down the answers: (1) Why do you/your family keep e-wastes at home rather than recycling them? (2) Do you care more about the e-wastes recycling after this course and who else do you think should know about it? The purpose of this activity was to extend what students learned in this lesson into real-life applications. Students would realize how close we are related to electronics and think about the difficulties in collecting e-waste from households to recycling companies.

Preliminary Findings

Student learning behavior: Based on the classroom observation, many students required assistance from the instructor on multiple occasions and needed many attempts to try designs independently (i.e., student performance would decrease if the teacher introduced the project with little follow up). When challenged, the behavior of students varied. For example, some students would ask the instructor more questions to guide design and other students would remain quiet with little help from the instructor. Due to the behavior observed during each session, the instructor included more interactive instructions and activities to enhance student engagement. When the instructor included more photos, diagrams, and interactions, students were more engaged versus when there was only plain text.

Enhanced students' enthusiasm: During the first session, students were very responsive to the "Name it" activity. The instructor set up a 15-minute time block, but students were unwilling to stop when the time was up and insisted on listing more everyday electronics. A 20-minute lecture was also given to familiarize students with the ideas of recycling and the concepts of electronic wastes and the associated toxicity. During the lecture, students gradually lost interests, especially in classes with over twenty students.

Figure 1: (left) The components of inside a waste hard drive. Disassembling work done by the students. (right) Sorted components after the sustainability module.

During the second session, most students showed significant interests and curious about dissembling hard drives, asking a considerable amount of questions even before the class started. The instructor showed an already-dissembled hard drive and elaborated the technical functions and the materials used in each unit and a step-by-step guide on dissembling. After the class, most students correctly differentiated various components such as printed circuit boards and silicon discs. Some students successfully related the material source to the components. Several students asked for permission to disassemble another hard drive after finishing the first one. Few asked to keep the printed circuit boards because they were interested in the structure, or because they realized PCBs contain valuable metals such as gold and silver.

Societal and economic awareness: During the third session, twenty-three out of one-hundred students submitted the PowerPoint slides for the "junk drawer" project. The majority of the students (16 out of 23) answered that they care more about electronic wastes after this course. The answers to the question "do you care more about the e-wastes recycling after this course?" included "toxic materials," "damage to the environment," and "recycling can help the planet." The answers to the question "who else do you think should know about e-waste?" included "everyone," "the adults," "more people," "the mayor," "the waste recyclers" (because of the profits), and "should not be shared." The answers to the question "Why do you/your family keep e-wastes at home rather than recycling them?" included "to sell them for money," "to fix them in the future," "as backups when other electronics broke down," "we don't know what to do with them," "we know valuable materials are in them," and "old electronics are memories." Two students reflected that though they knew recycling is critical for the sustainability of the electronic industry, they would still keep e-wastes at home because of the recycling fee for electronics. Responses from students concerning e-wastes related the environment (toxicity, environmental protection, etc.) with the societal aspects (human emotions, social roles, individual responsibilities, etc.) and economic aspects (valuable materials, recycling fee, recycling profits, etc.) towards sustainability.

Future Work

In this study, we created an educational module focusing on sustainable design and embedded it in a formal engineering-oriented class at a Midwestern public school. Under the framework of reflective practice, we conclude the following strategies:

Set various learning objectives: when applying or transplanting graduate-level concepts or ideas to junior high education, it is essential to set a reasonable expectation for students. Ideally, educators should design a range of expectations. For example, in our practice, only twenty-three students out of one hundred and two completed the "Junk drawer" assignment before the class started. Therefore, it is important to add additional objectives to the current lesson plan. For example, one modified objective could be: (1) All students will be able to remember the concepts of e-waste; (2) Most students will be able to explain the concept of sustainability and the issues about e-waste; (3) Some students will be able to think in life cycle assessment method.

Bridge the educational resource between colleges and the K-12 schools: one challenge of integrating sustainability into engineering education is the lack of resources and training for educators [13]. As K-12 courses often touch on lower-order concepts in engineering education compared to higher education, the required resources are less demanding. Current college educational resources on sustainability have vast potentials to transplant in the K-12 curriculum.

For instance, we reshaped the junk drawer project from a graduate-level course and triggered positive responses from the students. The strategies include avoiding jargons in the sustainability research and simplifying technical content but keeping the frameworks either in economic or societal aspects.

Conclusions

This study demonstrated that granting precollege children access to a sustainable design curriculum in the K-12 classroom can introduce the societal and economic aspects of sustainability to middle-school youth. In addition, the less-technological and society-oriented content in this educational module increased precollege students' interests in sustainability associated activities, triggering students' motivations for more entries into the future engineering pathway.

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