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Integrating Sustainability Grand Challenges and Experiential Learning into Engineering Curricula: Years 1 and 2

Claire Louise Antaya Dancz, Arizona State University

Ph.D. Candidate in Sustainable Engineering at Arizona State University

Kevin J. Ketchman, University of Pittsburgh
Rebekah Burke, Arizona State University
Dr. Melissa M. Bilec, University of Pittsburgh
Dr. Elizabeth A Adams, Chandler-Gilbert Community College

Residential Engineering Faculty at Chandler-Gilbert Community College.

Prof. brad allenby, Arizona State University
Prof. Mikhail Chester, Arizona State University
Prof. Vikas Khanna, University of Pittsburgh
Prof. Kristen Parrish, Arizona State University

Kristen Parrish is an Assistant Professor in the School of Sustainable Engineering and the Built Environment at Arizona State University (ASU). Kristen's work focuses on integrating energy efficiency measures into building design, construction, and operations processes. Specifically, she is interested in novel design processes that financially and technically facilitate energy-efficient buildings. Her work also explores how principles of lean manufacturing facilitate energy-efficiency in the commercial building industry. Another research interest of Kristen's is engineering education, where she explores how project- and experience-based learning foster better understanding of engineering and management principles. Prior to joining ASU, Kristen was at the Lawrence Berkeley National Laboratory (LBNL) as a Postdoctoral Fellow (2009-11) and then a Scientific Engineering Associate (2011-2012) in the Building Technologies and Urban Systems Department. She worked in the Commercial Buildings group, developing energy efficiency programs and researching technical and non-technical barriers to energy efficiency in the buildings industry. She has a background in collaborative design and integrated project delivery. She holds a BS and MS in Civil Engineering from the University of Michigan and a PhD in Civil Engineering Systems from University of California Berkeley.

Dr. Thomas P Seager, Arizona State University

Dr. Seager is an Associate Professor in the School of Sustainable Engineering & the Built Environment at Arizona State University in Tempe AZ.

Prof. Amy E. Landis, Arizona State University

Dr. Landis joined ASU in January 2012 as an Associate Professor in the School of Sustainable Engineering and the Built Environment. She began her career as an Assistant Professor at the University of Pittsburgh, after having obtained her PhD in 2007 from the University of Illinois at Chicago under the supervision of Dr. Thomas L. Theis. She has developed a research program in sustainable engineering of bioproducts. Her research ranges from design of systems based on industrial ecology and byproduct synergies, life cycle and sustainability assessments of biopolymers and biofuels, and design and analysis of sustainable solutions for healthcare. Since 2007, she has lead seven federal research projects and collaborated on many more, totaling over $7M in research, with over $12M in collaborative research. At ASU, Dr. Landis continues to grow her research activities and collaborations to include multidisciplinary approaches to sustainable systems with over 60 peer-reviewed publications. Dr. Landis is dedicated to sustainability engineering education and outreach; she works with local high schools, after school programs, local nonprofit organizations, and museums to integrate sustainability and engineering into K-12 and undergraduate curricula.

Integrating Sustainability Grand Challenges and Experiential Learning into Engineering Curricula: Years 1 and 2

Complex global challenges require multidisciplinary, sustainable solutions; the next generation of engineering students must be prepared to apply sustainability concepts to solve these challenges. Many undergraduate engineering students, however, report that they do not feel prepared to address these challenges because they were not introduced to these concepts during their engineering education. In addition, students report educational deficiencies of real world engineering and applied sustainability concepts as areas that need critical improvement in their education. This NSF TUES 2 project evaluates two methods for integrating grand challenges and sustainability into engineering curricula, termed as the *stand-alone course method*, and the *module method*. In the *stand-alone course method*, engineering programs establish one to two distinct courses that are designed to address sustainability grand challenges in depth. In the *module method*, engineering programs integrate sustainability grand challenges throughout a host of existing courses and weave student exposure throughout the curriculum. We are implementing and monitoring these two strategies in five different engineering programs, from research universities-extensive to community colleges; the collaborating institutions include the University of Pittsburgh, Community College of Allegheny County (located in PA), Arizona State University, Mesa Community College (located in AZ), and Laney College (located in CA). We have also engaged a sixth instruction to participate, Chandler-Gilbert Community College (located in AZ), due to the relocation of one of our collaborators.

This paper summarizes the progress and accomplishments during years one and two of this collaborative TUES 2 research project[1]. We review the development of ready-made, stand-alone sustainability courses and ready-made sustainability themed modules that employ experiential learning developed over the past two years. This review includes the packaging of three courses and fourteen modules on topics from green building to life cycle assessment to applied sustainability topics for engineers. In addition, we present the dialogues and critical collaborations that have lead to a successful first two years in establishing a stable network to explore both the stand-alone and module methods. Ultimately, through this TUES 2 research project, we aim to develop succinct recommendations regarding best practices for universities integrating sustainability and systems thinking into engineering curricula.

Summary of Course and Module Development

In Years 1 and 2, we developed three stand-alone sustainability courses that can be adapted for different levels of undergraduate curriculum: a course on green buildings and sustainable construction practices (GB), a course on life cycle assessment (LCA), and a Sustainability Topics course (Topics). Development of these courses included design of instructor materials for quick adoption and implementation, including: syllabus with ABET outcomes, sample course schedule, description and instructions for conducting experiential learning activities, lecture slides, homework assignments, sample course projects, exams, and pre- and post- course assessments. The courses and sample experiential learning activities conducted in each course are summarized in Table 1. In Y1 and 2, the GB course has been implemented at University of Pittsburgh and Laney College, the experiential learning activities and instructions for the LCA course have been tested in Dr. Khanna and Dr. Chester's classes, and the Topics course has been tested in Dr. Landis, Dr. Bilec and Dr. Allenby's classes. Adoption of the LCA and Topics courses at our partner institutions is planned for Y3.

Table 1. Summary of courses developed in years 1 and 2.

Course	**Description**	**Sample Activities**
Green Buildings (GB)	The green buildings (GB) course is designed to teach sustainability concepts throughout the design, construction, and use of buildings. Green building courses are currently a core requirement in construction engineering programs or for certificates in green building programs. This project adapts the existing GB course for sophomore to senior levels at community colleges.	Experiential learning activities include collecting and analyzing indoor air quality data and impacts of a building's performance on occupants. These activities can also be designed to employ service learning where students conduct energy assessments of local low-income housing in partnership with a local nonprofit. The energy assessments can be organized around one or more communities or within student housing.
Life Cycle Assessment (LCA)	The life cycle assessment (LCA) course is designed to teach students a method of quantifying the environmental implications of a product, process, or service through the use of LCA. The LCA course is adaptable for junior to senior level students.	The unique, multi-week experiential learning activities integrated into this course is built into the semester-long project. All the activities, from student-client project-scoping meetings to data collection, expand upon themselves culminating in a student-performed LCA.
Sustainability Topics (Topics)	The sustainability topics (Topics) course introduces students to the conceptual and practical challenges arising from the design, operation and management of sustainable systems. The course covers the NAE grand challenges, the basic concepts of sustainability, addressing the need for multidisciplinary approaches, and describes current patterns in technological evolution.	The experiential learning activities integrated into this course consist of student's creation of a photo glossary that will build in learning objectives and evaluating examples of sustainable technologies and grand challenges. Throughout the semester, students are asked to share their glossary and critically assess the sustainability of different technologies and case studies.

During the first two years of this TUES 2 project, we also created ten new modules on sustainability grand challenges that utilize experiential learning. The modules have been designed with flexibility for faculty to utilize them in a number of different courses at different levels. Modules have been designed to fit into approximately one week of lecture content and include the necessary instructor materials. The modules and a description of the experiential learning activity are described in Table 2. In Y1 and 2 we implemented the Model United Nations (UN), Life Cycle Thinking (LCT), Energy-renewables, Packaging, Technology Evolution, Sustainable Waste Management, Carbon, Water Footprinting at Arizona State University, LCT and Energy-renewables at University of Pittsburgh, and Water Footprinting at Mesa Community College and Chandler-Gilbert Community College. In Y3 we will implement LCT at Community College of Allegheny County and Laney College. The modules are available on our engineering education website (STEMed.engineering.asu.edu) for free download. In Y3 and 4 the modules and courses will be made available to the Nation's educators via the NSF National STEM Distributed Learning (NSDL) website, the Center for Sustainable Engineering (CSE) website. The LCA course and modules will be made available to the American Center for Life Cycle Assessment (ACLCA), GB course through PennState's National Energy Leadership Corps (NELC) website, and our Topics courses will be made available via our collaborator's publishers (e.g. at Pearson for Industrial Ecology and Sustainable Engineering).

Table 2. Summary of modules developed in years 1 and 2.

Module	Description	Notes
Model United Nations (UN)	A card game guides students through a model UN. One card describes the country, a set of cards identifies strategies, and events cards that the UN must address are held by the instructor.	Cards address topics of feeding 9 billion people, Carbon sequestration, managing the Nitrogen cycle, and information security
Life cycle thinking (LCT)	Students are given a product in class and asked to take it apart. Students then create a process flow diagram that includes life cycle flows of energy, materials, and emissions.	A variety of products are applicable (e.g. candy bar, small electronic, etc), enabling LCT in a wide array of classes. Advanced levels can quantify process material and energy flows.
Sustainability Metrics	Students are asked to bring a green product to class. Students investigate what metrics make it green, how to quantify and benchmark metrics, and how green metrics influence design[2].	Any product with a green label can be used: students can bring them to class or faculty can provide to students. Assignment can be modified to evaluate metrics or redesign products
Energy- supply, demand, and transmission	Students are given M&Ms to represent a unit of energy. Students calculate energy conversions, losses during transmission as energy (M&Ms) moves from the resource to the point of use.	Students can practice multiple skills by using Matlab to solve and graph information from their game. Different types of energy production systems can be included, including renewables. Activity can evaluate changes in supply and demand.
Energy- renewables	Students play the flash game Super Energy Apocalypse by Lars A Doucet. Groups are tasked with different energy strategies for developing the new world and they must assess their impacts.	Students can play remotely and tweet their progress. The module will also be designed to use the board game, Power Grid by Rio Grande Games for a more tactile experience.
Packaging	Students disassemble packaging for a line of products, weigh and catalogue the different materials, evaluate the effect of packaging on product safety, transportation, and materials use.	Packaging can be from a variety of products (cookies, DVDs, etc.). Students can redesign the packaging, calculate emissions and costs of shipping, and optimize product packaging and delivery.
Technology Evolution	Students create a timeline of a products' evolution. The cell phone is a classic example: students identify the major changes in technology over time and predict the next generation.	The timeline can address the connections between social values and design decisions, the systems connected to the designs, the evolution of emerging technologies.
Sustainable Waste Management	Students conduct a visual waste audit (e.g. watch and document what is disposed of in campus dining hall) and quantify how much waste ends up in different streams. Students determine where their waste goes, compare to alternatives.	The activity can be conducted either in or out of class to differing degrees of complexity; from simply discussing implications of waste management to calculating emissions from different manners of disposal (e.g. landfill, incineration)
Carbon, Water footprinting	Students use existing online tools to calculate either their carbon or water footprints. Students learn about embedded water, solutions for minimizing C and water emissions.	Students can be asked to compare the results from different tools, with the aim of critically evaluating information. Students can run the tool to test improvements.
Tragedy of the Commons	Students play out Harden's Tragedy of the Commons using gold fish. Students discuss ethics of sustainability. Note, this is a common exercise available in many versions.	One of our collaborations has developed a series of ethics games; one of which is a more complex version of the simple gold fish module.

Summary of Critical Collaborations

The collaborations that enabled a successful first two years of this program are summarized in Figure 1. Drs. Parrish and Bilec led the GB course development; in Y2 they identified and engaged Ms. McMahon at Laney College to implement the GB course in Laney's construction management program Spring 2015[3]. They also engaged Mr. Sandrock of Community College of Allegheny County to implement the GB course in Y3. Drs. Khanna, Chester and Landis have led the LCA course development during Y1 and Y2; they will engage an instructor in Y3 to implement the LCA course at our community college collaborators. Drs. Landis, Bilec, and Allenby have led the Topics course during Y1 and Y2; they will also engage an instructor in Y3 to implement the course at our collaborators' institutions. Drs. Landis and Bilec continue to collaborate and lead the graduate research associates in module development. The entire faculty team (Co-Is and senior personnel) also serves as faculty mentors to our community college collaborators.

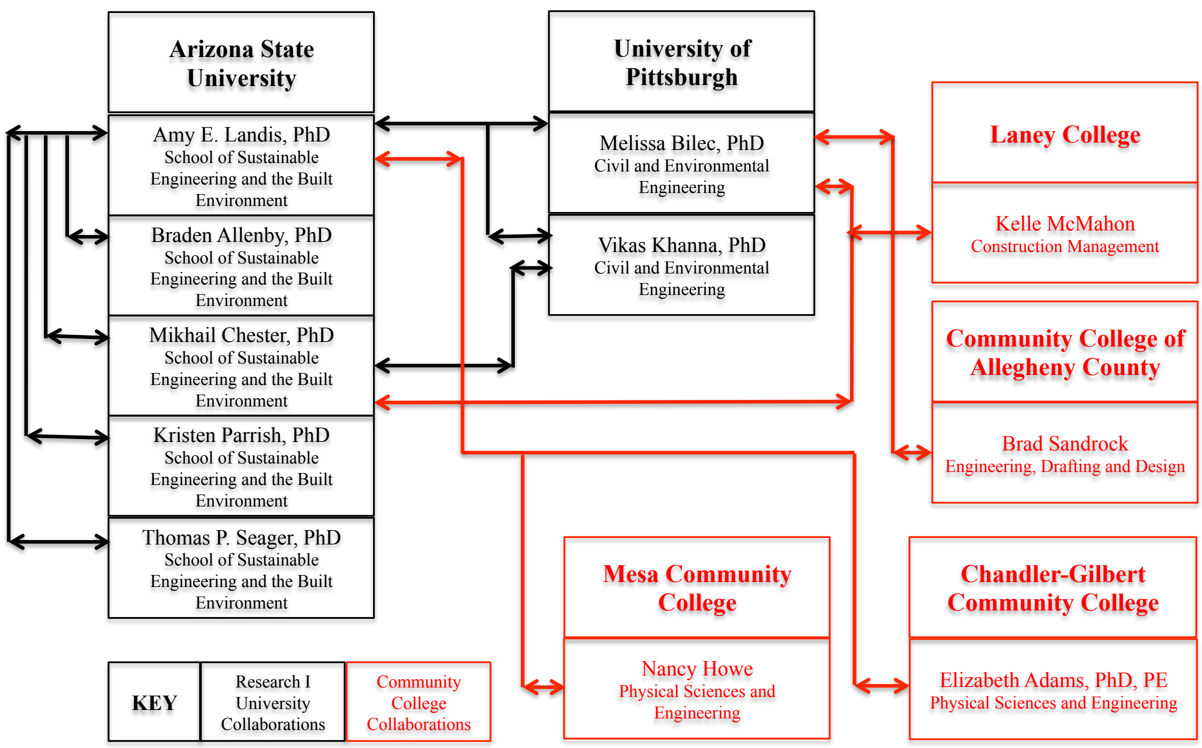

Figure 1. Summary of key research-I and community college collaborations established in Years 1 and 2. Research university-extensive collaborations are highlighted in **black**, while community college collaborations are in **red**.

Acknowledgments

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References

1. Antaya, C. L., M. M. Bilec, P. Rizzo and A. E. Landis (2013). Incorporating Sustainability into the Civil Engineering curriculum via cross course collaborations. American Society for Engineering Education, Atlanta, GA.
2. Antaya, C. L., E. A. Adams, K. Parrish, M. M. Bilec, V. Khanna, T. Seager, M. Chester, B. Allenby, J. M. Sims, N. Howe, and A. E. Landis. (2014). Integrating Sustainability Grand Challenges and Experiential Learning into Engineering Curricula: a TUES2 collaborative research project. American Society for Engineering Education, June 15-18, 2014 Indianapolis, IN.
3. Antaya, C. L., K. Parrish, E. A. Adams, and A. E. Landis. (2013). Experiential Learning in the Civil Engineering Curriculum: Collaborations between Community Colleges, Research I Universities and National Laboratories. American Society for Engineering Education, June 23 - 26, 2013 Atlanta, GA.