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# Put A Brick In The Toilet: Overcoming Student Perceptions of the Effectiveness of Naïve Environmental Solutions

**Theodore J. Hogan**
Northern Illinois University

**Paul Kelter**
North Dakota State University

**Abstract:** Eat local. Choose a reusable bag instead of plastic. Put a brick in the toilet. These are intuitively simplistic environmental "solutions" that may do little but make a person feel environmentally virtuous. Energy and environmental science teaching requires us to change students' preconceived simplistic notions about solving environmental issues if we want these future leaders to make real environmentally effective decisions. Students need to understand that the energy input in a disposable plastic bag is dwarfed by the energy expenditure of driving to the grocery store with a reusable bag, so that they don't make symbolic, but ineffective decisions. One approach is to have students attempt to develop a "sustainable" product. The complexity of environmental solutions becomes evident when we have to evaluate the energy use and environmental consequences from raw material sourcing to reuse.

**Key Words:** Design, Production, Energy, Materials, Complexity

*Theodore J. Hogan: Assistant Professor, College of Engineering and Engineering Technology, Northern Illinois University, DeKalb, IL, USA. Dr. Hogan worked about thirty years in industry and consulting prior to teaching, including as corporate head of safety and industrial hygiene for Commonwealth Edison. He uses this practical experience when teaching toxicology, safety, environmental health, and sustainability. As a member of the ACGIH Threshold Limit Values Chemical Substances Committee, Dr. Hogan develops workplace chemical exposure guidelines.*

*Paul Kelter: Professor and Director, Center for Instructional Excellence and Innovation and Center for Math and Science Education, North Dakota State University Fargo, ND, USA. Prof. Kelter is an analytical chemist who shifted early in his three-plus decade career to chemistry education, and more broadly, science education. He does work considering the relationship of science and society, with a particular focus on how such ideas and information can be used in teacher training.*

## Introduction

Policy decisions need to be based on facts, not beliefs. But many well-meaning efforts to address environmental sustainability are being made by decision-makers who focus on local or immediate concerns without an analysis of the full environmental consequences of their decisions. (Hardisty, 2012) Undergraduate students may also perceive that simplistic choices such as switching from disposable reusable plastic bags to paper will have significant climate benefits, despite contrary evidence from life cycle analyses. (Matilla, 2011) This may be due to what they learned in school; one university in the late 2000's actually suggested that putting a brick in the toilet would be an appropriate way to reduce water usage. But this will not save water if placed below the low water line (as the brick displaces a volume of water that is not part of the flush), and brick deterioration can damage the toilet.

Teaching incorrect and incomplete information can influence future decision-makers to make well-meaning but environmentally unproductive recommendations. There is a need for students to undergo a conceptual change about their sustainability thinking. (Duit, 2003) Students in all disciplines need to trade their pre-instructional concepts of sustainability from one of personal choices to a more meaningful approach that addresses large-scale actions and considers the full consequences of these actions. Fortunately, undergraduate sustainability education has been rapidly evolving into teaching students the complexity of the environmental issues and potential solutions. Our paper presents an approach to incorporating complexity-thinking decision-making into an undergraduate general education sustainability course. Complexity-thinking in sustainability is the concept that environmental systems and issues (and related decisions) are not isolated from each other, but are interconnected and need to be analyzed as part of a system, as a change in one factor may have positive or negative impacts on others. (Seager, 2013)

The course, entitled Pollution Prevention and Sustainable Production, is an evolution of a basic topic-by-topic (pollutants and health effects, air, water, land impacts) survey course. This is a university general education course, and is a part of the Engineering Technology curriculum. The original course did not provide connections between topics and had limited application of the information learned. The students left the course with environmental knowledge and few skills. Many students reported that the course also left them with environmental anxiety (due to a disparity between large-scale environmental issues and the inability of an individual to take action on those issues). (Cossman, 2013) The basic topics were still covered in the redesigned course, but the students had to apply this information to student-selected design projects which required them to understand the environmental impacts of each of their design decisions. Example project designs included: plastic picture frames made with a grain byproduct of ethanol fuel production; bamboo bags; phone cases; alternate energy lawnmowers; simple systems for identification of different types of scrap aluminum alloys; clothing recycling systems; computers made with obsolete cellphones and tablets. For example instead of a generic discussion about the environmental impacts of energy use, students determined a semi-quantitative assessment of the types and amounts of energy use (and mitigation) associated with their product, including resource extraction, transportation, and manufacturing. This approach provided students with an understanding of how to collectively and societally address sustainability issues, instead of relying on well-meaning individual consumer-based approaches like adding bricks and choosing different bags. (Sibbel, 2009)

The course project used active learning (also called engaged learning, student-centered, and other terms), which places students into a challenge-based environment where they have to solve real problems with real outcomes. (Haward, 2007. Prince, 2004) Active learning is a well-established approach (dating back to Socrates) that can be an effective supplement or even a replacement for traditional classroom (lectures, quizzes, papers, exams) teaching, and is aligned with long-established effective undergraduate teaching principles. (Chickering, 1987) It has been regularly incorporated into general environmental education courses, such as field work visits to environmentally sensitive sites like wetlands. Building on this long tradition, we suggest that the active learning approach presented here is one way students can learn how to become effective environmental decision-makers. (Pearce, 2010)

## Course Design

The Pollution Prevention and Sustainable Production course was a hybrid between traditional and active learning, as some research suggests that a variety of teaching methods should be incorporated in the classroom environment to accommodate different student learning styles (Felder, 2005). The course was taught in weekly three-hour evening blocks. Lectures were limited to around 30 minutes, and students participated in these with interactive engagement facilitated by open-book clicker questions throughout each lecture. (Caldwell, 2007) The rest of the class sessions were devoted to challenge exercises, sustainability group project work, and discussions. This structure was based on the concept that effective student learning is facilitated by lecturing less. (Knight, 2005)

### *Sustainable Design Project*

The structure of the sustainable design project was based upon one used by a California charter high school as part of an introduction to engineering course. (Summerrill, 2014) The excellent source material provided a structured framework with well-defined group assignments, including assignments for specific design deliverables. Additions included the use of "SolidWorks Sustainability" software to optimize selection and use of material in the design. This software use was optional for the engineering technology students who wanted the challenge of incorporating a more sophisticated design approach. However, all the students reviewed the SolidWorks Guide to Sustainable Design, as it provided a cogent explanation of a sustainable design process. (Dassault Systemes, 2014) Also included were assignments associated with the weekly environmental topic, such as climate change impacts of the product.

The basic project framework, as closely adapted from Summerrill, included:

- Links for project ideas
- Design team structure and operational principles
- Draft problem statement (functional needs of the end user)
- Draft problem definition (who, why, what, where, when, how) and draft project schedule
- Solution constraints (for example, use and availability of resources, manufacturing, price)
- Brainstorming on different ways to meet the specifications and constraints
- Sketches and notes for different designs
- Selection matrix, identifying strengths and weaknesses
- "Elevator Pitch" (Steinemann, 2005)
- Class presentations (limited to five slides)
- Narrative description of design selection

- Chemical hazard or mitigation of design
    - Persistent Organic Pollutants (Harrad, 2010)
    - Restriction on use of hazardous substances, RoHS (European Union, 2011)
    - Other hazardous material usage/mitigation
- Qualitative lifecycle analysis (Guinee, 2010)
- Project-related environmental impacts (materials extraction, materials production, transportation, energy, end of life/reuse)
    - Energy, climate change and air pollution impacts of resource provisioning
    - Water usage and water pollution from primary and secondary manufacturing processes
- Final design documents (includes refinement and inclusion of work from beginning of project)
    - Problem statement and definition
    - Schedule
    - Design selection
    - Design analyses
        - Functionality
        - Sustainability
        - Service life
        - Market and financial
        - Human factors (including safety, a degree concentration within the Engineering Technology curriculum)
        - Production
    - Drawings or mockups (including optional engineering drawings as described below)
    - Bill of materials
- Evaluation of final project
    - Did design meet specifications?
    - What change could improve the design?
    - How could sustainability of product be improved?
    - What would be done differently as a group?
- Final presentation of design

***Active Learning Exercises***

While a structured approach can be beneficial for complex active assignments, a variety of other active learning techniques were incorporated into the project and other course assignments, as multiple approaches to activity-based learning can be more effective than a single approach. (Hamer, 2000) One approach was to provide students with exercises that challenge their perceptions of trendy sustainability decisions, such as the desire by some to eat local food. These exercises required the students to bridge between their personal sustainability choices and the larger environmental implications of their decisions. Example exercises included:

- Quantify the water use impact of local food production. Students had to determine the water requirements for providing a simple breakfast of "local foods" consisting of eggs, toast, apple juice and coffee for 22,000 students eating 100 breakfasts a year. This points out the almost impossible task of providing “local foods” to a large population, due to adverse environmental impacts and the limitations of stores to provision different types of

foods from "local" farms. It also exposes students to the environmental impact and complexity of food production beyond the simplistic metric of "food miles."

- Calculate their "plastic bag miles." Students determined the gasoline equivalent in plastic bags that it would take to drive a car back and forth to the store carrying reusable bags to pick up whatever they are going to buy. Students learn that personal use of plastic bags has trivial resource use and environmental impact when compared to other personal fuel usage (unless they walk to the store).
- Environmental effects of daily habits: Students were challenged to consider one thing eaten or used on a daily basis (for example, a coffee cup, a cell phone or your automobile). Students discussed what was required to get the product to them and their impact on the environment. One quickly learns that bringing a reusable cup to the coffee drink store has few real environmental benefits in comparison with the adverse effects of filling up that cup.
- Find a hazardous waste site near their home. Students researched US Environmental Protection Agency and US Agency for Toxic Substances and Disease Registry to examine the local effects of improper waste handling. They described the site, the types and sources of major pollutants, the community affected, how people might get exposed, the potential health impacts on residents, and recommendations to address the situation. Students learn that not everything that is "local" is good for the environment.

These and similar exercises help students reframe their thinking about environmental sustainability by looking at relatable issues and the global impacts of their personal choices.

**Did the Students Buy In To This Instructional Model?**

***The Survey***

Twenty respondents filled out a seven-question survey administered after completion of the course, a 40% response rate. The survey, reviewed by Northern Illinois University Institutional Review Board and granted exempt status (#HS14-1022), is shown in Table 1. The survey included positive and negative questions to minimize both acquiescence bias (the tendency to agree by rote) and extreme response bias (the tendency to mark only the extreme responses). Seventy-five percent of the respondents were engineering technology majors, 10% were environmental studies majors, and 15% were other majors (including one business major). A total of 75% were junior and senior- level undergraduates. While this is expected (engineering technology students tend to transfer from other programs, or come in after completing community college), it also suggests the need to better market this general education course to freshman and sophomore non-majors.

The survey results tell us that students believe the Sustainable Design project helped them understand the core concepts of sustainable development (Q#1), and that they appreciated the nuanced (complex) thinking that is part of evaluating the fate of a product as it goes from raw material through reuse (Q#2). Students supported the contention that the learning activities helped them learn to consider real environmental issues (Q#3). SolidWorks was familiar to many of the students from their work in prior courses (Q#4). The project assignments were not as clear as some students would have liked (Q#5), but students strongly supported the assertion that the group activities were an effective way to parse the work (Q#6). Many students agreed that the assignments interrelating the sustainable design project and the textbook chapters were of value

in tying together text information and real-world situations (Q#7). The surveys showed that the majority of the goals of the project matched the outcomes.

***The Comments***

The surveys included ample room for comments about each question, and students took advantage of the space. Table 2 gives representative comments for each question.

Students conducted post-project analyses to identify what they learned and what they would do differently. One group, which designed a cell phone case using either conventional plastics or E. coli-based plastics, submitted a very thoughtful analysis. E. coli can be manipulated to make a plastics feedstock, including1,4-Butanediol (BDO). (Lee, 2011) Because this group made full use of the SolidWorks Sustainability software, they were able to quantitatively evaluate whether their product would make a real difference. Their sustainable project design self-analysis included these verbatim comments:

- The changes that could be made to the design would be to eliminate one design completely since it is a raw material product. Another change that could be made if we didn't eliminated one product completely would be to use some kind of non-toxic plasticizer, which is still being researched on which one to use.
- The only way for our product to be more regenerative would be for consumers to recycle the product and not throw it away.
- Our group learned that our product really isn't getting recycled; it is getting down-cycled. One thing our group would have done differently after doing research would be to pick a different product, one line of product is relatively sustainable and while our other process turned out be just a way to make BDO out of bacteria that really isn't sustainable.
- As a group we would eliminate our green product line and possibly pick a new product to produce, even though our project turned out well we were not satisfied with results we got as far as really being sustainable.

Embodied within these comments is a demonstration of the effectiveness of using a design project to teach the complexity of environmental sustainability.

**Discussion**

Recent research suggests active learning should replace traditional STEM teaching methods (Freeman 2014): "The results…support active learning as the preferred, empirically validated teaching practice in regular classrooms." But are students ready to learn this way, particularly since most of their academic experience is in traditionally structured courses? While some aspects of active learning in this course were well-received by students, the survey feedback and the course classroom experience indicated that an active learning experience (particularly one so dependent on group work) may be an uncomfortable experience. Students are conditioned to expect bounds on their assignments, with right and wrong answers. A passive learning experience may actually be preferred by more experienced students. (Messineo, 2007) Teachers need to understand and address student concerns and perceptions to construct a satisfactory active learning experience. (Hall, 2011)

The sustainable design project heavily relied on group work. Student expectations and experience of group work are often negative, even though research supports the effectiveness of group work on student learning outcomes (Livingstone, 2000). Even if effective, improperly

structured group work can contribute to student anxiety. Insufficient guidance on project scope was a factor when there was student dissatisfaction. Providing more guidance on project selection, and early guidance and intervention on apparently dysfunctional groups, would make for a more successful student learning experience.

Individual teaching styles may need to be adjusted within the active learning framework. Insufficiently explaining core concepts before the assignments can limit the effectiveness of active learning. One cannot rely solely on an active learning assignment to teach both concepts and applications. Active learning assignments that are too loosely structured may fail to convey expectations to students, creating student anxiety and missing the opportunity for them to learn the desired lessons. Finished active learning assignments need to be presented by students or discussed with the class to complete the learning experience. Written homework feedback is insufficient, as there is a need to address the inherent ambiguity and complexity contained within sustainability decision making. This may mean covering fewer topics to make time available for completing the active learning process.

## Conclusions

Students addressing sustainability still need to learn how to deal with incomplete information and relatively unstructured assignments, as this is their future sustainability decision environment. (Chin, 2006) Their sustainability decisions are going to be constrained by incomplete information, resources and capacity limitations, and conflicting goals. (Meder, 2013) But it is very hard for students to reframe their right/wrong coursework learning expectation. It may get worse for future students encountering active learning due to the pervasive emphasis on K-12 math and reading performance testing. (Dee, 2010) An approach for teaching how to become more comfortable with complexity decision making is to give some in-class "learning assignments," not graded assignments. Students can be coached in-class through these exercises, provided with verbal feedback, and written comments without grades on turned-in work. Conducted frequently at the beginning of the course, learning assignments can help students overcome active learning anxiety.

Students (whatever their course of study) need to understand that substituting reusable bags for disposable plastic bags will not "save" the environment. We need to learn how to think about the decisions that we make as individuals and societies. Students can learn to raise the right questions and analyze the data that they collect to arrive at meaningful answers. These answers may not always be the tropes that are so much a part of our day-to-day discussions and actions, but in the end, they will lead to more meaningful choices.

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Accessed June 27, 2014

Table 1: Survey Questions (Responses in %)

| *Question* | *Strongly Agree* | *Agree* | *Neither Agree or Disagree* | *Disagree* | *Strongly Disagree* |
|---|---|---|---|---|---|
| *1. The Sustainable Design Project helped me understand the core concepts of sustainable development.* | 45 | 25 | 15 | 0 | 15 |
| *2. The complexity of environmental solutions becomes evident when one has to evaluate all phases of a product from raw material sourcing to reuse.* | 45 | 50 | 10 | 0 | 10 |
| *3. The Sustainable Design Project learning activities did not help me learn how to evaluate and discuss real environmental issues.* | 5 | 5 | 20 | 45 | 25 |
| *4. The Design Project introduced me to the use of SolidWorks as a tool for sustainability.* | 5 | 15 | 25 | 15 | 30 |
| *5. The Sustainable Design Project weekly assignments were not clear.* | 0 | 15 | 30 | 45 | 10 |
| *6. In-class Sustainable Design Project group activities were an effective way to ensure group members did their fare share of work.* | 35 | 35 | 10 | 5 | 15 |
| *7. The assignments tying the Sustainable Design Project and the textbook chapters(such as air and water pollution) helped me understand how to apply the textbook information to real-world situations.* | 10 | 45 | 10 | 30 | 5 |

Table 2: Representative Comments For Each Question

| *Survey Question* | *Student Comments* |
|---|---|
| *The Sustainable Design Project helped me understand the core concepts of sustainable development.* | *-It allowed me to look at the bigger picture of sustainability. I was able to think and analyze product life cycles and improve on components of our design through this analysis.*<br>*-After knowing, or creating a life cycle assessment of a product, we went through the process of greening it. That alone was such a headache and now I have a better understanding of why our world is the way it is. So glad this project is all about understanding the core concepts, and trying to green just one product of our own.*<br>*-It got me thinking of the actual process of making things and how every little thing matters*<br>*-Opened my eyes to a wide range of factors that should be considered when dealing with sustainability.* |
| *The complexity of environmental solutions becomes evident when one has to evaluate all phases of a product from raw material sourcing to reuse.* | *-Having to look at entire production and mining processes, I was surprised at how much work went into evaluating prices.*<br>*-I feel that this project helped me understand every aspect of the environmental impacts that a product creates. As mentioned above, the project provided examples to learn from. I really liked the variety of different aspects that were looked at during the project. It allowed everyone to learn to look at every aspect of the product.*<br>*-By going into detail with a specific product it allowed for a wide range of research about all the different stages of sustainability.* |
| *The Sustainable Design Project learning activities did not help me learn how to evaluate and discuss real environmental issues.* | *-They did help to understand real life possibilities that occur daily.*<br>*-It help me understand how bad the environmental really is.* |
| *The Design Project introduced me to the use of SolidWorks as a tool for sustainability.* | *-Due to project choice, Solidworks was not necessary.* |
| *The Sustainable Design Project weekly assignments were not clear.* | *-Sometimes the instructions were unclear, but after discussing them with the professor, they became straightforward.*<br>*-They were clearly explained on Blackboard (Note: Blackboard is a web-based learning management system). The wording might be repeated which could* |

| | |
|---|---|
| | *cause confusion.* |
| *In-class Sustainable Design Project group activities were an effective way to ensure group members did their fare share of work.* | *-In class group assignments taught me that communication is important and various things can go wrong if all members are not present. This can get overwhelming for group members who are actually doing work.*<br>*-I agree with this, as a group we split the assignments and worked on our own parts. Having time in class ensured that group members there will complete their part.* |
| *The assignments tying the Sustainable Design Project and the textbook chapters(such as air and water pollution) helped me understand how to apply the textbook information to real-world situations.* | *-Yes, I think the assignment when we had to research close to our hometown was helpful.*<br>*-Opened my eyes to pollutants that I had no idea were even considered to be bad or harmful.* |

Photo for paper (picture taken by Theodore J. Hogan)

Theodore J. Hogan

Paul Kelter