

Life Cycle Assessment and Economics in First Year Engineering

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Work in Progress: Life Cycle Assessment and Economics in First Year Engineering

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Abstract:

Approximately three years ago, a module on life-cycle assessment was incorporated into an Introduction to Engineering course that is open to all first-year undergraduate students at Loyola University Maryland. This paper will describe the module, its development, and subsequent revision. Future work will be conducted with a colleague from the Department of Economics. The module begins with a viewing of “The Story of Stuff,” produced by Annie Leonard of Greenpeace. This video is a robust critique of the lifecycle of consumer products. Coupled with a second video with a tough opposing view, students are introduced to two fundamentally different political and philosophical viewpoints. Students are asked to write immediate in-class, anonymous responses to both viewpoints. The instructor collects and collates these responses, highlighting major themes and utilizing student quotes. Discussion in the following class session is based upon these responses with the intent to initiate deeper insight and critical analysis. For example, given the common issue of how national budgets and percentages are presented in both videos, there is a chance to segue into the ways data is presented and the “problem with percentages.” A document unique to this module is introduced referencing the data in full and discussing the important idea that data needs to be referenced with appropriate proportions and units (per capita, per mile, per GDP, etc.) and can be easily distorted when the reference base is changed (e.g. from total budget to discretionary budget). Another major theme in both videos is that of growth and its limits; this is again a natural starting point to introduce students to the foundational concepts in macroeconomics of the question of commodities, an S-curve of development with creative destruction, and the Ehrlich-Simon bet. The conclusion of the module requires students to write a reflective essay where they analyze the presentations more formally for the intended audience, author biases, and methodologies. The students are asked to find one thing they agree with and disagree with on both sides of the debate. Current students (2017) seem to readily accept ecological concerns about consumerism and show a desire for fairness and equity. This author believes those attitudes are well established in current K-12 education. This provides a nice frame, as time allows, to introduce principles from sustainability engineering and design, which are intended to analyze rigorously the externalized costs of production, consumption, and associated necessary infrastructure. This then lends itself to the application of a rapid “ecoaudit” to assess areas of impact under different design scenarios. This can be accomplished using materials selection software CES Edupack 2017 (Granta Design Limited, 2017).

Introduction and Background

Teaching economics for engineers has been a long established part of an engineer's education. Typically it is covered in textbooks which discuss "engineering economy" defined in one text as an approach whereby "economic merits of the different alternatives available to the solution of a given problem can be evaluated in a systematic manner" [1]. Understanding techniques and concepts such as time-value of money and cash flow is certainly a priority, but this study wants to begin to answer questions about students' implicit understanding of macroeconomic principles and foundational attitudes towards long term economic prospects, natural resources, commodity prices, and optimistic or pessimistic outlooks on the future of technological development and product R&D.

The researchers are interested in measuring students' general attitudes towards product development and consumption. One question they ultimately want to answer is whether those attitudes differ between engineering students and other students. To that end, the researchers wished to present a learning module around questions of consumption and critical economic analysis. Outcomes assessment of student learning through the module is not addressed here. Additionally, the foundational question of what are the most important concepts and skills for engineering students to learn about economics is also not addressed. Rather, the researchers felt a lesson about consumption and critical analysis of economic data had intrinsic value for engineering students and wanted to ascertain student general attitudes towards these issues.

Relevant Literature

A literature search determined that little has been explored in the area of linking economics and engineering, especially in introductory engineering courses. At one community college a reorganizing of an introduction to engineering design course included first-year acculturation to college skills as well as interaction with sophomore students in design teams. This now two-year program allows sophomores to investigate engineering management, ethics and economics [2]. Another source correlates understanding life cycle assessment (LCA) data with effective decision making while noting that students need training in applying economic concepts. The authors describe how LCAs were developed to "help students think about sustainability metrics in the context of economics." [3].

Story of Stuff

This study started about three years ago in an Introduction to Engineering class. This class is part of a first year seminar program that is required of all first year students. Students, regardless of major, can choose this course as one of their seminar courses. Students were shown two videos about the materials economy called "the story of stuff" and "critique" story of stuff" [4]. "Story of stuff" is an animated short film produced by Annie Leonard of Greenpeace. It presents an analysis of materialism, consumption, and capitalism from a progressive perspective, while the opposing video might be considered a conservative or libertarian view. In asking students to respond to both videos in reflection essays they were asked to find one thing they agreed with

and one thing they disagreed with in each presentation. One issue that emerged from their responses was how they viewed data, facts, and statistics. An observation by the author is that students wish to strive for an “appearance” of critical thinking or rigor by mentioning the idea of data, facts, statistics, without having a clear understanding of what questions they should really be asking as a consequence. We often leave such critical thinking skills to implicit learning by exposure and observation.

The Problem with Percentages

Specifically, both videos wanted to make claims about military spending. Statistics were quoted in both videos about the size of the U.S. military budget. Not surprisingly the more progressive or “left” video quoted the budget as being about half of the overall budget, while the more libertarian critique said that it was on the order of 20% of the budget. Students argued this point not based on data, or thinking of a question to ask, but rather on what sounded or felt right to them. Consistently they backed this up by saying that he did a better job of providing data and facts than the original video. This difference in the quoted statistic lead to a class discussion and document about “the problem with percentages” and emphasized how important the denominator or reference was in creating relative fractions or ratios. This turned into an excellent opportunity to discuss this important concept in critical understanding and reasoning, that any statistic, any percentage needs to be in relation to some base number, this applies to ideas such as *per capita* or per mile, which are crucial for an engineering economic analysis of any large project.

The Bet of Ehrlich and Simon

In addition some Web resources were provided about the famous Ehrlich-Simon bet about the cost of materials [5]. *The Bet*, [6] is a book that details a famous bet between Paul Ehrlich, Biologist and Environmentalist and Julian Simon, Economist. Simon won the bet over the decade 1980-1990. The lesson for students is that inflation adjusted prices of natural resources have a negative, not a positive trend, over sufficiently long periods of time. It is exactly this kind of insight, and arguments about the mechanisms that might give rise to it, that could be useful for engineering students in their careers. If they work as project planners and managers, it is valuable to understand these larger trends and what they might mean for product development. It can promote a mindset sensitive to the impact of such external trends.

Lifecycle Assessment, Planning, Design

Students were also introduced to the concepts of Biomimicry and Lifecycle Assessment (LCA) in this course.

Life Cycle Assessment, as defined by SETAC, is “a process to evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying energy and materials used and wastes released to the environment; to assess the impact of those energy and material uses and releases to the environment; and to identify and evaluate opportunities to effect environmental improvements” [7, 8].

Its main advantage over other, site-specific, methods for environmental analysis, such as Environmental Impact Assessment (EIA) or Environmental Audit (EA), lies in broadening the system boundaries to include all burdens and impacts in the life cycle of a product or a process, and not focusing on the emissions and wastes generated by the plant or manufacturing site only. [9]

This statement aligns closely with the statements made in “the story of stuff” and so makes the video and general discussion of economic models an excellent entry into discussions of LCA.

Paper vs. Plastic

A class period was devoted to a discussion of “paper vs. plastic” in the context of an Eco-audit. (Appendix D). Students were generally surprised that the answer to the question of which material is preferable was not as straightforward as they initially thought. An important concept in LCA is the consideration of the boundary of the system. Where one draws that boundary, what one considers to be inside or outside of the system, when doing such an analysis is important to understanding why the results of a LCA can be complex and counter-intuitive.

Attitude Survey

In spring 2018 students in the Introduction to Engineering class took a survey about their attitudes and beliefs [Appendix A]. It was intended to provide a quick snapshot of how students saw the long term trends in product development and pricing and how that might influence their decisions and outlooks.

Results and Analysis

The survey was administered to a single seminar section with an enrollment of n=16. Although this creates a large uncertainty in the results, the students’ answers hint at some interesting questions to pursue in future (Appendix A). One can summarize the results of this preliminary study into a narrative description of a typical first year potential engineering major, with six major statements as shown in Table 1, “narrative conclusions from student survey”. Table 2, “summary of survey questions and results from Introduction to Engineering Seminar (n=16)”, summarizes the statistical results from the survey questions. These data suggest that engineering students see the value in learning economics and believe in the efficient working of the market. Interestingly they are split on the question of the role of government in protecting the population. An unexpected survey response was that they don’t feel a need to buy the latest products and say they do admire ‘beautiful’ objects. We did not explore their understanding of the term beautiful in this context.

In looking at student comments about the two videos from 2017 and 2018 it may be possible to discern a generational shift whereby some of the basic premises about allocation of resources and equity are already deeply embedded in young adults [Appendix B]. This is true even as these same students show evidence for strongly held pro-business beliefs, what might be characterized

as “libertarian” views. [Appendix C]. Thus, there may be little advantage to presenting information about things students have already accepted and it might be more useful to expand upon other ideas and generate a next level of questions in the college classroom to address their concerns about practical implementation and the consequences of various environmental and sustainability goals.

Conclusions and Future Work

It is desirable to expand the content and topics covered about economics for engineering students. This study looks at ways to do so and hopes to look at impacts on the attitudes of engineering students towards resource allocation and conservation. It is hoped this will be expanded to other students of other disciplines (such as economics) and student populations to see if engineering students fundamentally approach these topics with a different outlook and set of attitudes.

APPENDIX A: SURVEY QUESTIONS ON STUDENTS' ECONOMIC ATTITUDES AND BELIEFS

1. It is important to an employer for engineers to know economics.
Strongly agree Agree Disagree Strongly disagree
2. Designers should consider the political situations of countries that supply resources for products.
Strongly agree Agree Disagree Strongly disagree
3. Generally speaking, I expect the price of my consumer electronics to reflect the total costs involved in making the product, including materials and labor.
Strongly agree Agree Disagree Strongly disagree
4. Generally speaking, I expect the price of consumer electronics to decrease with time.
Strongly agree Agree Disagree Strongly disagree
5. Generally speaking, I make conscious choices to buy things which are recyclable.
Strongly agree Agree Disagree Strongly disagree
6. I am confident that the federal government regulates industrial pollutants to protect my health and that the products I buy contain safe materials.
Strongly agree Agree Disagree Strongly disagree
7. Generally speaking, I make conscious choices to buy things which will last a long time.
Strongly agree Agree Disagree Strongly disagree
8. Generally speaking, I would consider myself an optimist about my future.
Strongly agree Agree Disagree Strongly disagree
9. I think that we will have to ration electricity in my lifetime.
Strongly agree Agree Disagree Strongly disagree
10. I think that there are technological solutions to environmental problems.
Strongly agree Agree Disagree Strongly disagree
11. I admire and enjoy beautiful everyday products.
Strongly agree Agree Disagree Strongly disagree
12. I have to buy a new phone every two years.
Strongly agree Agree Disagree Strongly disagree

APPENDIX B: Responses to “Story of Stuff” (Quotes from Students)

I never realized just how much time we spend looking at advertisements.

What really struck me during this video is how the US and advertisement can corrupt the people enough to throw away the useable things just to buy new things from a company. This corruption takes away from others and this is wrong.

I am really worried about our resources and the amount we have left.....

I was interested about the fact that manufacturers purposely make inferior products and the amount of truth behind it.

I didn't realize how much we waste in production.

How can I break the cycle?

We are in a continual cycle of shopping and most of our goods only last short term.

What would it take to change this system?

How long til this cycle catches up with us and we run out of resources?"

Consumer culture is destroying our planet.....

The fact things are so cheap due to other's expense

This seems outdated and doesn't truly talk about the recycling that goes on. She is way too negative about this.

I strongly disagreed with the idea of planned obsolescence. While yes products are constantly evolving to meet the eyes of the consumers, most realize, even if they are unhappy with what they have, they cannot afford to constantly buy new things.

This entire video is biased and ignores a lot of important facts. The part about external costs is very biased and I would agree not completely true.

Why hasn't anyone tried to change the system?

Is there a way to regain natural supplies?

Is this all ultimately more damaging or more beneficial to the entire planet?

Is there a way to make things better?

Why don't more people know about this? (these externalized costs)?

I was surprised at the huge repercussion on society and the earth.

When we create products, how can we make them in the most efficient way and accurately account for what impact it'll have on our environment?

How can we do better?

How can some items cost so little?

How is this legal? I am confused that we are destroying the environment and doing nothing about it.

What's the solution?

What can normal people do to stop the exploitation of the world's resources?

Isn't anyone doing things to prevent this?

If we know all of this why don't we do anything?

APPENDIX C: Responses to “Story of Stuff” Critique (Quotes from Students)

Sometimes what he said was not well thought through.

Who do we listen to? I have no clue what is the truth anymore. All I want is to help the earth. Both videos are trying to make you listen to them, but who is right?

Much better and showed actual facts.

Very good rebuttal. However, he did seem to overstate and exaggerate sometimes.

I find it funny that both videos contradict each other. One uses sources and evidence while the other does not.

She manipulated stats and wording to make things seem more extreme than they were in reality.

I think that both sides of the argument are polarized, with the second having much more impact due to it citing its source, and citing them correctly.

I had a lot of similar thoughts and felt that her statistics were slightly exaggerated. I’m glad someone fact-checked her.

What is true? She seemed like she didn’t do correct research but should we still keep mindful of what she is saying even though the guy tells us otherwise?

The critique didn’t mention any of the previous argument’s points when they were accurate. He simply ignored it.

It was too liberal and anti-government to start and he proved her wrong with facts.

The fact that we barely scratched the surface of resources used.

By shifting the data or showing data in part, the woman was able to skew the information to favor her argument.

We, as citizens, have responsibility/opportunity to make our lives successful in our own ways so that we can have the life we choose to have. The government has a responsibility to make sure we are safe and our human rights are preserved, not to give us what we need.

Where’s the middle ground between these two?

How can two people have such different views on the same topic?

Who is right? Both videos have completely different message but what is the right message?

Who is credible?

What are the credentials of the people from both videos?

“ .without the ability to fact check her, I just trusted it. I should have remembered to question everything.”

That the first video is being very misleading toward young people, by blatantly ignoring facts and paraphrasing to prove her point is really disappointing.

How can someone misrepresent data so many times in one video?

"so when we stop using that one resource to find another we don't help the limited resource. It is not valuable anymore, we found an alternative, so why should we help the limited resource grow?"

What can we do to make sure we use our resources in a more re-usable manner, and ensuring we are using what we've got in the best way possible? How can we share this with developing nations?

If both of the speakers think they are right, then how to improve our planet?

After watching the criticism, I wonder if there is a way to conserve resources in a better way.

He makes it seem that nothing bad will happen?

Can they both be sort of right?

APPENDIX D: [10]

Required Energy and Materials

Many resources, such as energy and water play a major role in the production of either type of disposable bag.

- Plastic bags require 58 gallons of water to produce 1500 bags. Paper bags require 1502 gallons of water to produce 1500 bags.
- Plastic bags require 71% less energy during the production process and 36% less nonrenewable energy during their life time than paper bags.
- Plastic bags require 17 BTU's to recycle. Paper bags require 1,444 BTU's to recycle.

Wastes generated

- Paper is biodegradable, which results in less litter production.
- If disposed of in a landfill paper bags produce higher global warming potential.
- Paper bags generate almost 5 times more waste than plastic bags.

Air and Water Emissions

- Pulping processes, and bleaching if applicable, produce more air emissions and water contaminants than plastics manufacturing.
- Plastic bags create 4,645 tons of CO₂ equivalent per 150 million bags.
- Uncomposted paper bags generate 7,621 tons of CO₂ equivalent per 150 million bags, and composted paper bags generate 14,558 tons per 150 million bags.

Qualitative Analysis

The preferred product may not always be chosen according to energy or water requirements. Ultimately, the user must decide which bag material they prefer based on the factors they value as the most important.

Table. A qualitative comparison of paper and plastic bags.

| Bag Type | Required Storage Space | Reusability | Energy Production Demand | Marine Risks | Biodegradability |
|-----------------|-------------------------------|--------------------|---------------------------------|---------------------|-------------------------|
| Plastic | Lower | Higher | Lower | Higher | Generally Lower |
| Paper | Higher | Lower | Higher | Lower | Generally Higher |

Plastic bags, compared to paper bags, occupy less space because they are more compressible, require less energy to produce, and lend themselves better to reuse. On the other hand, plastic bags pose a greater risk to marine life, like sea turtles, because the sea turtles mistake plastic bags for jellyfish when they are hunting for food. Paper bags are also generally more biodegradable than plastic bags except in the case of bags made of biodegradable plastics. In respect to biodegradability, neither plastic nor paper bags biodegrade in landfills because landfills are purposely designed to prevent liquids from leaching and contaminating water supplies.

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Table 1: Narrative conclusions from student survey

| |
|--|
| It is important and valuable for an engineer to know politics and economics and useful to their employer. |
| They believe in the rational nature of the market and that price reflects true costs. |
| A traditional technocratic stereotype; they enjoy and admire beautiful products that are long-lasting and represent value. They are generally optimistic and believe there are technological solutions for what ails us. |
| They don't feel the need to keep up with purchasing new phones every two years, which is in line with an engineer enjoying a well-used and functioning product. |
| They evenly split on the federal government's role and ability to protect us. This reflects our current societal dilemmas. |
| Recyclability does not influence purchasing. (This is not the same as saying that one does or does not recycle). |

Table 2: Summary of survey questions and results from Introduction to Engineering Seminar (n=16)

| Question Number | Brief Description | % agree/strongly agree | Sentiment Summary |
|-----------------|--|------------------------|-------------------|
| 12 | I buy phone every two years | 0.25 | No |
| 9 | Rationing gas will happen | 0.33 | No |
| 5 | Ability to recycle important when purchasing | 0.36 | No - weak |
| 6 | Government should protect citizens | 0.50 | Split |
| 4 | Prices decrease with time | 0.64 | Yes - weak |
| 8 | Optimist | 0.83 | Yes |
| 7 | Longevity of product important | 0.92 | Yes |
| 10 | Tech solutions exist | 0.92 | Yes |
| 11 | Enjoy beautiful products | 0.92 | Yes |
| 1 | Should know economics | 0.93 | Yes |
| 2 | Should know politics | 0.93 | Yes |
| 3 | Price reflects costs | 0.93 | Yes |

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