Teaching Sustainability in Cal Poly Electrical and Computer Engineering Programs

- Approaches for lower division, upper division and grad courses
- Opportunities for SLOs

David Braun, Art MacCarley, John Oliver
Electrical & Computer Engineering
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June 22, 2009
EE 111 – Freshman Seminar (first course taken by EE freshmen)

One week devoted to making new students aware of the importance of electrical engineers to the solution of environmental problems: “A New Role for Engineers, Scientists and Hands-on Problem Solvers”

• Just as technology played a major role in creating the problem, people look to technology to solve the problem.

• Reality: Even those of us that are deeply concerned secretly hope that there is a technical solution out there that will allow use to continue our present lifestyle.

• Technology comes from the minds and hands of scientists and engineers. We play a very special role not only in the problem, but the potential solutions to it.

• Since we have always come through in past challenges, it’s expected of us.

• While the complete issues are vastly larger and more complex than just the technical problems, we still possess a disproportionate responsibility for shaping the destiny of the planet.

http://www.eia.doe.gov/oiaf/ieo/figure_11.html
http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/rea_sum.html
Increasing awareness: a new code for ethical practices

Old:
• I just create or work on the technologies. I am not responsible for their use.
   “I just do what I’m paid to do.”
• Financial or social self-interest
  “Gotta have that Hummer”
• Intellectual self-interest
  “Research for the sake of grant funding”

Note that these attitudes are only obliquely addressed in current codes of ethics: see http://www.nspe.org/Ethics/CodeofEthics/index.html or http://www.ieee.org/portal/pages/iportals/aboutus/ethics/code.html

New:
• I have an ethical obligation to use our knowledge and skills for the betterment of the planet.

• I am willing to take responsibility for what I create.

• Look beyond the narrow focus of any educational discipline; see the big picture.
2. Engineers shall at all times strive to serve the public interest.

2.E. Engineers are encouraged to adhere to the principles of sustainable development\(^1\) in order to protect the environment for future generations.
Manufacturing Costs of Microprocessors

- 2 GJ of energy to manufacture a 300 mm² wafer
  - Roughly the energy in 200 gallons of gasoline
  - 34 MJ of energy required to manufacture a 100 mm² Processor (includes assembly)[1]

- Processors are everywhere!:
  - Over 1.7B Cellular phones in use
  - Over 58M iPods manufactured
  - Over 21M Nintendo DS systems manufactured

- 1.7B Cellular Phones ~ 1.7B 20mm² processors
  - 18,700 Tera Joules!
  - ~500 pounds of Uranium-235
  - ~150 M gallons of gasoline
    - Yearly consumption of the United States

Idea: Processor Re-Use
Food-Chain

[Bar chart showing BDTmark for different categories like Dig. Video Camera, PDA, Set Top Box, Cell phone, Printer, Automotive Nav. System, Portable Game Systems, Home Stereos, Toys, MP3 Players, White Goods, Home Tools]
Idea: Processor Re-Use Food-Chain

- Processors are energy-intensive to manufacture
- Re-use processors from old devices in, “next generation” devices
  - Next gen. devices should have equal or lower computational demand
- Creates a processor “food-chain”
  - Extends the lifecycle of the processor
  - Need to balance with in-use consumption
  - Life Cycle Analysis (LCA) based on energy
Teaching and Assessing Multidisciplinary Sustainability Analysis

- Sustainability Confronts the Technical Mindset
- Assessment results
- Weekly Assignments

[http://digitalcommons.calpoly.edu/susconf/52/](http://digitalcommons.calpoly.edu/susconf/52/)

David Braun – Electrical & Computer Engineering
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Aug. 1, 2008
How to Prepare EE 347 Lab Reports

First A. Author, Member, IEEE, Second B. Author, Jr., and David Braun, Senior Member, IEEE

I. INTRODUCTION AND LEARNING OBJECTIVES

This section provides context for the experiment, defines the experimental topics, and explains the learning objectives. Write this section before class.

Cal Poly EE laboratory courses typically prepare students to meet at least ABET outcomes 3a, 3b, 3c, 3e, 3g, and 3k: (a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(e) an ability to identify, formulate, and solve engineering problems
(g) an ability to communicate effectively

II. SUSTAINABILITY ISSUES

Use this section to analyze sustainability issues associated directly or indirectly with your experiment. Sustainability describes a condition in which natural systems and social systems survive and thrive together indefinitely [2]. A sustainable condition allows people to meet the needs of the present without compromising the ability of future generations to meet their own needs [3]. Because humanity now consumes and pollutes the Earth’s resources faster than natural and human systems can replenish and clean them, we do not currently live in a sustainable manner [4]. It might prove helpful to consider Commoner’s laws of ecology, which sound unsurprisingly similar to laws of physics:

- Everything connects to everything else
- Everything must go somewhere
- Nature knows best and bats last
- There is no such thing as a free lunch [5].

Explain how experiment topics or applications related to the experiment foster or prevent sustainability [6]. Reference [7] and others on Blackboard™ provide helpful information. Consider issues related to Energy, Environment, Economics, and social or political Equity, four “E”s of sustainability.

III. TROUBLESHOOTING

Document any troubleshooting completely, both in your lab notebook and in this section of your lab report. If something goes wrong, explain your methodical approach to resolving the problem. Document hypotheses developed to explain any difficulties, explain how you tested each hypothesis, and document any fixes implemented.

IV. POST-LAB QUESTIONS

Answer all post-lab questions. The EE 347 lab manual hides post-lab questions in sneaky places so read carefully.
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\[
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REFERENCES


EE 413 Advanced Electronic Design (4)

Advanced design of electronic circuits and subsystems. Sustainability. Design as a process. Implementation of specific design projects. Teamwork. Automated test using GPIB instruments. 3 lectures, 1 laboratory. Prerequisite: CSC 101, EE 409 & 449.

2009-2011 Cal Poly Catalog
Apply green engineering principles to the design process

1. Engineer processes and products holistically, use systems analysis, and integrate environmental impact assessment tools.
2. Conserve and improve natural ecosystems while protecting human health and well-being.
3. Use life-cycle thinking in all engineering activities.
4. Ensure that all material and energy inputs and outputs are as inherently safe and benign as possible.
5. Minimize depletion of natural resources.
6. Strive to prevent waste.
7. Develop and apply engineering solutions, while being cognizant of local geography, aspirations, and cultures.
8. Create engineering solutions beyond current or dominant technologies; improve, innovate, and invent (technologies) to achieve sustainability.
Current Efforts

- LCA in undergraduate Electrical Engineering classes @ Calpoly
  - Not always best to minimize circuit area
    - Measure performance vs. power consumption vs. area
    - Same processor core, different amounts of cache
EE 514 – Advanced Topics in Automatic Control (Grad Course)

Final project: Apply advanced control theory to environmental policy.

Teams of two, 10-page report and 15-minute PowerPoint presentation.

Perform literature search to identify a model of an environmental process affected by human activity, e.g., the thermal balance or the atmospheric carbon balance of the planet, the oxygen content of the oceans. Justify assumptions and simplifications.

Use MATLAB Simulink® to simulate a first-order model of the process.

Investigate the use of any three advanced control laws (e.g., optimal control, fuzzy-logic, variable structure control) as the basis of policies that regulate the process, rather than existing crude control laws.

Use these to assess environmental benefit compared with existing laws.

Moral: advanced control theory isn’t just for jet engines or robots – we need world leaders that understand these methods – maybe you?
Project results and effectiveness assessment:
Seven class projects:

• “Optimal control of Global Temperature through regulation of CO₂”
• Assessment of the effectiveness of the “Gas Guzzler Law”, and areas for improvement via improved regulatory strategies.”
• “Green conversion: an alterative tax structure for electricity usage”.
• “Ramifications of absolute EV mandates” compared with regressive feedback regulation of mobile emitters.
• Feedback control of ocean O₂ via large-scale iron oxide addition.
• Life-cycle product investment for considering environmental impact.
• Ethanol – a closed-loop environmental assessment

Cost functions:
• \( C_a \) is an integral of a function (ca) of carbon dioxide emission rates
• \( C_d \) is an integral of a function (cd) of temperature rates

\[
C_a = \int_{t_0}^{t_f} c_a(s(t), \delta(t), \delta(t), t) \, dt
\]
where

\[
c_a = \left[ \left( \frac{1}{\tau_a} - r \right)^2 + \tau_i^2 r^2 + \tau_e^2 q^2 \right] e^{-\frac{t}{\tau_a}}
\]
**EE Curriculum**

**B.S. DEGREE**

**ELECTRICAL ENGINEERING**

Cal Poly, San Luis Obispo

**2009-11**

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<td>EE 111/151</td>
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<td>(ECE 228 w AC)</td>
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**Blue** – discussed today, instructor dependent

**Red** – already require sustainability analysis

**TOTAL: 194**
Which is NOT one of the 3 most cost effective ways to reduce carbon emissions?

Measure in $ per ton CO$_2$ saved

A. Coal power plant carbon capture and storage
B. Solar photovoltaic power generation
C. LED lighting in commercial buildings
D. Hybrid cars
Figures removed due to lack of copyright.

Available online at Nat Geo website

Peter Miller, "Saving Energy Starts at Home," National Geographic, 215(3), March 2009, p. 60-81

Teaching Sustainability in Cal Poly Electrical and Computer Engineering Programs

- Approaches for lower division, upper division and grad courses
- Opportunities for SLOs
  - Teach in previously untapped courses
  - Pave the way to curriculum reform

David Braun, Art MacCarley, John Oliver
Electrical & Computer Engineering
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June 22, 2009
We define sustainability as the ability of the natural systems and social systems to survive and thrive together to meet current and future needs. In order to consider sustainability when making reasoned decisions, all Cal Poly graduates should be able to:

1. Define and apply sustainability principles within their academic programs.
2. Explain how natural, economic, and social systems interact to foster or prevent sustainability.
3. Analyze and explain local, national, and global sustainability using a multidisciplinary approach.
4. Consider sustainability principles while developing personal and professional values.

http://www.calpoly.edu/~acadsen/agendas/08-09_agendas/sa0602.pdf