Exposing First-Year Students to Green Engineering

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Abstract

The Division of Engineering Fundamentals provides a "home" for incoming freshman engineering students and most transfer engineering students during their first year at Virginia Tech. Here the students are given a prelude to the academic and professional future that lies in store for them through a required two-course sequence, Introduction to Engineering I and II (EF1015 and EF1016). Through these two courses, the Division has a unique opportunity to expose the 1200+ first-year engineering students to the concerns of green engineering. Currently EF1015 is designed to introduce students to the engineering disciplines and to aspects of the engineering profession. The course uses various types of problems, from multiple disciplines, to engage the new engineering student in standard problem solving techniques. By altering some of the problems to include green content, the concerns of green engineering can be presented to the students as a common aspect of engineering problem solving, rather than as a separate topic. Through EF1015 and EF1016, the Division is the bridge to all degree granting departments within the College of Engineering at Virginia Tech; the green modifications, currently in progress, will facilitate meeting the College's goal that every engineering graduate is exposed to environmental issues and is made aware that engineering systems have environmental consequences. The paper includes the plan, a sample problem, and a discussion of the implementation of the plan. This work was first presented at the Virginia Tech Green Engineering Conference in July 2001.

Introduction

First-year students often enter university education without a clear idea of where they are headed. Many enter engineering colleges because they excel in math and science classes and have always been told that "engineering" is the right place for them to be. The Division of Engineering Fundamentals (EF) at Virginia Tech exists to help these students bring their talents and interests into perspective and, if engineering is indeed the right place for them, select an engineering discipline. In this formative role, the Division has a unique opportunity to introduce the concerns of green engineering to the 1200+ students who pass through the program each year with their first steps toward a Virginia Tech engineering degree. The effort described herein promotes a green awareness throughout the required first semester engineering course, EF1015. The approach used presents green issues as commonplace aspects of any engineering system,

rather than as separate concerns reserved for environmental engineers. This approach is supported by the study of engineering ethics in EF1015, wherein interpretation of the fundamental canon to protect the safety, health, and welfare of the public¹ implicitly requires protection of the environment. The balance of this communication begins with a brief description of the Division of Engineering Fundamentals, the Division's function within Virginia Tech's College of Engineering, and EF1015. This is followed by an overview of the plan to implement green awareness in EF1015 and a synopsis of the first semester of the effort.

Engineering Fundamentals

The Division of Engineering Fundamentals functions as a home-base for incoming freshman and most transfer engineering students during their first year at Virginia Tech. Students are introduced to engineering through a required two-course sequence, Introduction to Engineering I and II (EF1015 and EF1016), taught by EF faculty. The faculty instructor for their first course in the sequence (EF1015) also serves as the students' academic advisor, generally until they transfer to a degree-granting department within the college of engineering. For the majority of students, the transfer occurs after successful completion of the freshman year requirements, which include Chemistry, Math, Physics, and English credits along with the EF sequence. The Division also offers two freshman-level electives (a green engineering lecture series and a hands-on lab) and upper-class courses in computer programming and design that are required by some of the ten degree-granting departments within the college. A more complete description of the freshman program can be found elsewhere.²

A screening of the incoming class with regard to math abilities and science backgrounds generally places about 1250 students in EF1015 during the fall semester. This group is divided among 40+ sections, yielding approximately 30 students per section. EF1015 spring semester enrollment is about 350, with the majority of these students revisiting the course.

EF1015, Introduction to Engineering I, is a two-credit hour course set up to introduce the students to the engineering disciplines and to the engineering profession, particularly ethics. A major portion of the course is devoted to introductory treatment of specific topics that the students are likely to encounter in-depth later. These topics include: general problem solving; data analyses involving the graphing of linear, power, and exponential functions; basic use of MATLAB; and algorithm development, which includes flowcharting and computer programming (using MATLAB). This organization of the course allows students to sample the "flavor" of different engineering disciplines through problem solving and to get some first hand knowledge of the dedication required to obtain an engineering degree.

The Green Initiative in EF1015

Rather than approach green engineering as a separate topic with a set of specific problems to solve, the approach used introduces a green awareness to students through expansion of traditional problems to include environmental issues. As an example, consider the usual mass balance problem for the production of orange juice concentrate. Typically such a problem asks for the mass of water evaporated from fresh juice (12% solids) to produce a certain amount of

concentrate (42% solids). Stating the problem in this manner is simple and elegant, but omits the inherent green content and, in fact, omits a significant amount of the engineering content. To amend the situation, the process description is expanded and, from that, a computational problem that links environmental concerns to the process is extracted. Such an attempt for the orange juice problem is offered here, along with a suggested “solution.”

Orange Juice Problem^{3, 4, 5}

Orange juice is a product of Florida that is shipped to many other locations for consumption. After extraction, screening, and pasteurization, some of the fresh juice is packaged in plastic or glass bottles or waxed cardboard cartons and shipped refrigerated. Juice processed and sold this way is called Not From Concentrate (NFC) orange juice and has a 12% content (by mass) of soluble solids that are mostly sugars. It has a shelf life of approximately two months. Alternately, the fresh juice is fed to evaporators operating under vacuum and heat where it is concentrated to a level of 65% soluble solids by removing water. This bulk concentrate is stored frozen, at approximately 10°F, until required. To produce the Frozen Concentrated Orange Juice (FCOJ) found in supermarkets, the bulk 65% concentrate is mixed with fresh juice and water to obtain a 42% soluble solids concentrate. FCOJ is packaged in fully plastic cans or in waxed cardboard cans with metal ends in 6, 12, and 24 ounce sizes. It must be kept frozen, but has an extended shelf life of approximately two years. Consumers who purchase the frozen concentrate add 3 parts by volume water to reconstitute the juice before drinking it. The bulk concentrate produced with evaporation can also be processed into Reconstituted Ready-To-Serve (Recon RTS) juice with the addition of water and, for flavor, oils and essences obtained from the orange peel. Recon RTS juice is packaged in waxed cardboard cartons or glass or plastic containers, requires refrigeration, and has an expected shelf life of about two months. All forms of orange juice are usually pasteurized before reaching the consumer.

If we assume that the juice is composed of only soluble solids and water, how much fresh juice is required to produce 500 pounds mass of bulk concentrate in the evaporation process? How much water is removed to produce the 500-lb_m of bulk concentrate? How much FCOJ can be produced from the 500-lb_m bulk concentrate if the fresh juice added is 10% of the product FCOJ?

Environmentally speaking, what are the issues associated with the production and distribution of orange juice in each form (NFC, FCOJ, and Recon RTS)? Which of these environmental issues are *major* considerations in providing Florida orange juice to New York City, to Minnesota, to Alaska, to Hawaii, to Arizona, and to Georgia?

Why do orange juice distributors make Recon RTS juice? Since it is essentially the same as NFC juice, are they just wasting energy?

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<p>ORANGE JUICE PROBLEM</p> <p>GIVEN: SEE DIAGRAM</p> <div style="text-align: center;"> <pre> graph LR FJ["FJ FRESH JUICE 12% SOLUBLE SOLIDS 88% WATER"] --> EVAPORATOR EVAPORATOR --> W["W PUR E WATER 100% WATER"] EVAPORATOR --> BC["BC = 500 lbm BULK CONCENTRATE 65% SOLUBLE SOLIDS 35% WATER"] </pre> </div> <p>REQ'D: MASS OF FRESH JUICE, FJ MASS OF WATER REMOVED, W MASS OF FROZEN CONCENTRATE PRODUCED FROM BULK MIXED WITH FRESH JUICE AND WATER (SEE PG 2), FCOJ</p> <p>ENVIRONMENTAL ISSUES FOR PRODUCTION / DISTRIBUTION OF NFC, FCOJ, AND RECON RTS TO NEW YORK CITY, MINNESOTA, ALASKA, HAWAII, ARIZONA, AND GEORGIA</p> <p>WHY MAKE RECON RTS? WASTE OF ENERGY?</p> <p>RELATIONSHIPS:</p> <p>1. CONSERVATION OF MASS: MASS IN = MASS OUT</p> <p>ASSUMPTIONS:</p> <p>1. FRESH JUICE IS COMPOSED OF SOULBLE SOLIDS AND WATER ONLY (WE ARE NEGLECTING ANY PULP PRESENT)</p> <p>SOLUTION:</p> <div style="display: flex; justify-content: space-between;"> <div> <p>1. MASS OF FRESH JUICE, FJ MASS BALANCE FOR SOLUBLE SOLIDS</p> $(0.12) FJ = (0.65) BC = (0.65) (500) \text{ lb}_m$ $FJ = 2708.33 \text{ lb}_m \approx \underline{2700 \text{ lb}_m \text{ OF FRESH JUICE}}$ </div> <div>REL #1</div> </div> <div style="display: flex; justify-content: space-between; margin-top: 20px;"> <div> <p>2. MASS OF WATER REMOVED, W OVERALL MASS BALANCE</p> $FJ = W + BC$ $2708.33 = W + 500$ $W = 2208 \text{ lb}_m \approx \underline{2200 \text{ lb}_m \text{ OF WATER}}$ </div> <div>REL #1</div> </div>				

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<p>ORANGE JUICE PROB. CONT.</p> <p>BC = 500 lb_m BULK CONCENTRATE 65% SOLUBLE SOLIDS 35% WATER</p> <p>FJ FRESH JUICE 12% SOLUBLE SOLIDS 88% WATER</p> <p>W PURE WATER 100% WATER</p> <p>MIXER</p> <p>FCOJ FROZEN CONCENTRATE 42% SOLUBLE SOLIDS 58% WATER</p> <p>GIVEN: FJ = (0.10) FCOJ</p> <p>3. MASS OF FROZEN CONCENTRATE, FCOJ REL #1</p> <p>MASS BALANCE FOR SOLUBLE SOLIDS</p> <p>$(0.12) FJ + (0.65) BC = (0.42) FCOJ$</p> <p>$(0.12) (0.10) FCOJ + (0.65) 500 = (0.42) FCOJ$</p> <p>$FCOJ = 796.57 \text{ lb}_m \approx \underline{800 \text{ lb}_m \text{ OF FROZEN CONCENTRATE}}$</p> <p>4. ENVIRONMENTAL ISSUES OF PRODUCTION / DISTRIBUTION OF:</p> <p><u>* NFC (NOT FROM CONCENTRATE) JUICE</u></p> <p>PRODUCTION - EXTRACTION, SCREENING, PASTEURIZATION (ENERGY)</p> <p>STORAGE - PROBABLY NEAR 40°F, REQUIRES REFRIGERATION (ENERGY); STORAGE SPACE MAXIMIZED, STORAGE TIME MINIMAL (MONTHS)</p> <p>PACKAGING - WAXED CARDBOARD (WASTE), GLASS (RECYCLABLE), PLASTIC (MOST RECYCLABLE); PACKAGING A READY-TO-SERVE PRODUCT REQUIRES MAXIMUM AMOUNT OF PACKAGING MATERIAL</p> <p>TRANSPORTATION - 40°F REFRIGERATION (FUEL / ENERGY); SHIPPING RTS PRODUCT MAXIMIZES SHIPPING WEIGHT AND VOLUME (FUEL / ENERGY)</p> <p>CONSUMER USE - RTS; SHORT TERM STORAGE; DISPOSAL OF PACKAGING (RECYCLE OR LAND-FILL)</p>				

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	<p>ORANGE JUICE PROB. CONT.</p> <p>4. CONT.</p> <p><u>* FCOJ (FROZEN CONCENTRATE ORANGE JUICE)</u></p> <p>PRODUCTION - EXTRACTION, SCREENING, PASTEURIZATION, EVAPORATION, MIXING BULK CONCENTRATE WITH FRESH JUICE AND WATER (ENERGY)</p> <p>STORAGE - NEAR 10°F, REQUIRES REFRIGERATION - FROZEN (ENERGY); STORAGE SPACE MINIMIZED, LONG TERM (YEARS) STORAGE POSSIBLE</p> <p>PACKAGING - WAXED CARDBOARD (WASTE) - METAL ENDS (RECYCLABLE), PLASTIC (MOST RECYCLABLE); PACKAGING A CONCENTRATED PRODUCT MINIMIZES AMOUNT OF PACKAGING MATERIAL REQUIRED COMPARE 800 lb_m FCOJ TO 2700 lb_m FJ</p> <p>TRANSPORTATION - 10°F FREEZER (FUEL / ENERGY); SHIPPING CONCENTRATED PRODUCT MINIMIZES SHIPPING WEIGHT AND VOLUME (FUEL / ENERGY) COMPARE 800 lb_m FCOJ TO 2700 lb_m FJ</p> <p>CONSUMER USE - RECONSTITUTION REQUIRED (AVAILABILITY OF CLEAN, FRESH WATER); LONG TERM STORAGE; DISPOSAL OF PACKAGING (RECYCLE OR LAND-FILL)</p> <p><u>* RECON RTS (RECONSTITUTED READY-TO-SERVE) JUICE</u></p> <p>PRODUCTION - EXTRACTION, SCREENING, PASTEURIZATION, EVAPORATION, RECONSTITUTION (ENERGY)</p> <p>STORAGE - PROBABLY NEAR 40°F, REQUIRES REFRIGERATION (ENERGY); STORAGE SPACE MAXIMIZED, STORAGE TIME MINIMAL (MONTHS)</p> <p>PACKAGING - WAXED CARDBOARD (WASTE), GLASS (RECYCLABLE), PLASTIC (MOST RECYCLABLE); PACKAGING RTS PRODUCT REQUIRES MAXIMUM AMOUNT OF PACKAGING MATERIAL</p> <p>TRANSPORTATION - 40°F REFRIGERATION (FUEL / ENERGY); SHIPPING RTS PRODUCT MAXIMIZES SHIPPING WEIGHT AND VOLUME (FUEL / ENERGY)</p> <p>CONSUMER USE - RTS; SHORT TERM STORAGE; DISPOSAL OF PACKAGING (RECYCLE OR LAND-FILL)</p>			

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	<p>ORANGE JUICE PROB. CONT.</p> <p>5. MAJOR ENVIRONMENTAL ISSUES ASSOCIATED WITH DESTINATIONS:</p> <p>NEW YORK CITY - TRANSPORTATION, WATER AVAILABILITY, PACKAGING DISPOSAL</p> <p>MINNESOTA - TRANSPORTATION</p> <p>ALASKA - TRANSPORTATION, SHELF LIFE</p> <p>HAWAII - TRANSPORTATION (SEA OR AIR), SHELF LIFE, WATER AVAILABILITY, PACKAGING DISPOSAL</p> <p>ARIZONA - TRANSPORTATION, WATER AVAILABILITY</p> <p>GEORGIA - ANY?</p> <p>6. WHY PRODUCE RECON RTS?</p> <p>ORANGES AND THEIR FRESH (NFC) JUICE ARE SEASONAL AND PERISHABLE COMMODITIES. FOR CONSUMERS AND LOCALITIES THAT REQUIRE OR PREFER A READY-TO-SERVE PRODUCT, RECON RTS OFFERS YEAR-ROUND AVAILABILITY OF SUCH ORANGE JUICE. ALSO, AS AN AGRICULTURAL PRODUCT, AVAILABILITY OF DOMESTIC NFC ORANGE JUICE IS AFFECTED BY WEATHER, PEST POPULATIONS, AND ANY OTHER AGENTS THAT INFLUENCE THE FLORIDA GROWERS' ABILITY TO BRING RIPE ORANGES TO MARKET. IN YEARS OF POOR HARVEST, AVAILABILITY OF RECON RTS (AND FCOJ) WILL STABILIZE ORANGE JUICE PRICES AND REDUCE THE NECESSARY AMOUNT OF IMPORTED JUICE (E.G., FROM BRAZIL). THESE ARE THE REASONS THAT ENERGY IS SPENT IN PRODUCTION OF RECON RTS.</p>			

Implementation

The effort to promote green awareness in first-year engineering students was implemented in fall 2001. Modifications to the Introduction to Engineering I course (EF1015) involve coordinating the instruction of thirteen faculty members, resulting in a need to introduce change somewhat slowly. In the first semester of the effort, two substantial homework problems involving significant green content were added to the syllabus. In addition, the new engineering students were required to attend a special evening lecture very early in the semester, which focused on the engineer's role in sustaining the environment.

The gathering of the 1200+ first-year engineering students at an evening lecture during the first week of classes served several purposes. First, it provided an opportunity for the students to identify with the College of Engineering early in their academic career. More importantly, the speaker, Judge Hullihen Williams Moore, impressed upon the students the responsibility they, as engineers, will have in meeting the needs of the present without detriment to the future. Judge Moore is a Commissioner of the State Corporation Commission of Virginia and a member of the Board of Directors and the Committee on Electricity of the National Association of Regulatory Utility Commissioners (NARUC). With humor and thought provoking questions and statements, Judge Moore highlighted personal links between the students and the environment in illustrating the importance of green concerns in their careers and lives.

The sample problem presented earlier in this work was one of two “greened” engineering homework problems assigned during the semester. The other problem was based on one developed by Pritchard and Holtzapple⁶ to examine technical issues arising from an ethics case-study film entitled *Gilbane Gold*⁷. Used in conjunction with viewing of the video, the *Gilbane Gold* problem provides a means to couple the problem solving aspects of the course with the study of ethics and a means to emphasize green considerations. Instructors were encouraged not to introduce or label the “green” problems as such, but instead to impress upon the student that green considerations are a typical part of engineering endeavors. Both the orange juice problem and the *Gilbane Gold* problem provide a qualitative overview of green issues. But, lively class discussions resulting from the review of these problems indicate that this level of treatment was sufficient to make an impact. In addition, the personal link provided by problems involving ordinary products like orange juice and water introduce green concerns at a meaningful level for the students.

Future Plans

The green initiative in first-year engineering studies at Virginia Tech began with small but strongly positive changes in the first semester Introduction to Engineering I course in the fall 2001. The invited lecture that kicked off both the academic careers of a new class of engineering students and the program was a great success. Both the College of Engineering and the Division of Engineering Fundamentals are committed to making this an annual event. Plans for future semesters also include expanding the number of assigned problems that will include green considerations and expanding the number of engineering disciplines from which the problems are drawn. Our objective in EF1015 remains to develop a green awareness that students will

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carry with them through their discipline specific course work and, it is hoped, through their engineering careers. Additionally, if the problems used offer a personal link to the students, the green awareness generated may also compel students to make everyday product/disposal choices that are less costly to the environment.

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