

## **AC 2007-1826: ASSESSING AND IMPROVING A MULTIDISCIPLINARY ENVIRONMENTAL LIFE CYCLE ANALYSIS COURSE**

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# Assessing and Improving a Multidisciplinary Environmental Life Cycle Analysis Course

## Abstract

We describe learning and assessment from the spring 2006 Environmental Life Cycle Analysis (LCA) course, an upper-level undergraduate multidisciplinary course taught to students from a variety of engineering disciplines at Virginia Polytechnic Institute and State University (Virginia Tech). The interdisciplinary background of the students and their general lack of exposure to the systems-based concepts of the Life Cycle Assessment method pose challenges for effective teaching and learning of the course objectives. We assessed the overall effectiveness of the current teaching materials and methods with respect to students achieving the learning objectives in this class. The data and conclusions are primarily based on a pre- and post-course survey – one provided to the students on the first day of class and a second with identical questions given at the end of the class. The survey responses and data analysis provide objective data demonstrating that the class objectives were met as well as support for course changes considered by the instructor. While the surveys provided useful assessment information, we found that a lack of clarity in the specific survey questions was a limitation. Moreover, the surveys were not designed to provide information to assess multidisciplinary learning and team skills. These skills need be explicitly stated as learning objectives and also assessed specifically to be more effectively learned.

## Introduction

The ability of students to work effectively in interdisciplinary teams is recognized as a key skill in corporate and governmental settings. Multidisciplinary teams are critical in industry to bring together the diverse skills sets required to design, manufacture, test, market, and sell products. Multidisciplinary teams have been used effectively at national labs for decades and are essential for approaching problems that require a wide array of skills and that are too complex for research teams based in any single discipline.<sup>1</sup> In an increasingly global and competitive world, these skills are anticipated to be even more crucial for success. The National Academy of Engineering's report, *Educating the Engineer of 2020*, identifies collaboration by a multidisciplinary team of experts as a growing need due to the increasing complexity and scale of systems-based engineering problems.<sup>2</sup> Finally, this skill is explicitly required by the ABET Engineering Accreditation Commission Criterion 3 (d) which states that engineering programs must demonstrate that their students attain “an ability to function on multidisciplinary teams.”<sup>3</sup>

While multidisciplinary teamwork is understood to be an important skill set for students, universities have difficulties implementing such interdisciplinarity into curricular and degree programs which are generally discipline-focused. However, emerging issues in the areas of the environment and global sustainability now provide a compelling framework for both teachers and students to view engineering from a broader perspective. The next generation of engineers is likely to face a number of serious challenges in their careers with respect to the environment, from local to global scales. Energy demand is growing due to population growth and affluence at the same time that non-renewable fossil fuels, the world's primary source of energy, are being

depleted. Ecosystems are also under stress as resources are depleted and pollution in various forms accumulates.<sup>4</sup>

To minimize the impact of engineering activities on the environment, it is critical that students develop skills to approach engineering from a system's perspective. These skills include detailed analyses of the entire life cycle for products, processes, and systems by considering materials extraction, manufacturing, distribution, disposal and the associated environmental impacts, which necessarily crosses engineering disciplines. This approach is not common to most discipline focused courses in colleges and universities and provides opportunities to address two additional ABET criteria under Criterion 3: (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; and (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.<sup>2</sup>

## **Background**

Life Cycle Analysis (LCA) is a methodology to quantitatively assess the overall environmental impact of products, processes, and systems. LCA is an invaluable tool for assessment of environmental impact based both on data and the entire life cycle. ENGR 3134, *Environmental Life Cycle Analysis*, is an upper-level undergraduate course at Virginia Tech which instructs students on the concepts and methods of LCA. This class is available for students from all twelve (12) disciplines in the College of Engineering as part of the Green Engineering Program which strives to increase student awareness regarding the impact of engineering practice on the environment as well as to teach students engineering design and analytical skills to minimize such impacts. This class provides an excellent opportunity to develop both systems-based perspectives and multidisciplinary team skills.

Environmental Life Cycle Analysis is a three-credit undergraduate course typically taken by junior and senior level students. In spring semester 2006, the enrollment was 33 students with 30% females - double the overall female percentage in Virginia Tech's College of Engineering. The disciplinary breakdown for the class was 17 industrial systems engineers, 10 mechanical engineers, 3 civil/environmental engineers, 2 chemical engineers, and 1 materials science engineer. A more balanced distribution of student majors is desired for this class, but very difficult to control. Key barriers limiting students in some disciplines from taking this class include: (1) a lack of awareness of this class among the many offered in this large engineering school; (2) schedule conflicts with required in-major courses; (3) a lack of free technical electives; (4) the exclusion of this class from technical elective checklists; and (5) limitations on the size of the class. Written descriptions of this course as well as seminars within each discipline at the sophomore level are being prepared to help overcome the first barrier above. The other barriers are more complex and will take time to minimize or eliminate.

The class was primarily taught in a traditional lecture format to build up the concepts and skills required for a final multidisciplinary team LCA project. The learning objectives, grading metrics, and syllabus for the class are included for reference in the appendix. Since no textbook was found to cover the course material appropriately across the disciplines, a wide variety of

materials (book chapters, journal and newspaper articles, corporate product information, web databases, and software manuals) were provided to the students to complement the lectures. The class was taught by faculty with disciplinary backgrounds in materials science and chemical engineering. The primary instructor also has several years of experience in Design for Environment (DfE) and Life Cycle Analysis methods practiced currently in industry. The use of faculty from other disciplines was considered for specific topics within this course, but unfortunately, the concepts covered are not commonly known or used by most engineering faculty. Therefore, appropriate multidisciplinary faculty were not available at this institution to provide significant value to the class. The use of industrial practitioners and/or faculty expertise from other institutions would be valuable to augment the course content with regard to specific disciplinary concepts.

Two software packages were integrated into the class. CES Selector provides materials selection based on multi-dimensional engineering design criteria including environmental factors.<sup>5</sup> SimaPro7 is an LCA package which allows full life cycle analysis to be modeled for products, processes, and systems.<sup>6</sup> The challenges of using software packages were factored into the decision to use them in the course; the ability of the software to demonstrate the complexity of multi-dimensional engineering problems and to analyze detailed LCA models was thought to outweigh the concerns of integrating software into the course.

Individually, students were challenged to work outside traditional disciplinary boundaries through assignments which considered all four life cycle phases – extraction, manufacturing, use, and disposal – for a specific material/product combination. For example, students had to consider where raw materials originated, how they were obtained, what processes were needed in manufacturing, how much energy was required for use, and what disposal options were available. Brief reports were required for each phase of the life cycle for the student's chosen material and product. When all stages were completed, the students presented their findings individually to the entire class in a 5 minute presentation designed to improve communication skills, promote student-to-student teaching of multidisciplinary topics, and cover a wide range of materials. The materials (products) selected by the students cross all main materials categories and examples include: wood (paper), nylon (carpeting), platinum (fuel cell), copper (tubing), hemp (biomass fuel), and glass (windows).

Multidisciplinary team skills were developed through a major team project worth 35% of the students' grades. Six teams consisting of either 5 or 6 students were assigned through a random lottery that was constrained to ensure students from multiple disciplines onto each team. Teams had at least two industrial systems engineers, two mechanical engineers, and one engineer from one another discipline. The project used the SimaPro software to model the life cycle of a product chosen by the team from extraction through manufacturing to use and, finally, product disposal. Within product boundaries selected by the teams, an inventory of all inputs and outputs was compiled. From this inventory, scientifically-derived characterization factors were used to translate the outputs to overall quantitative environmental effects across multiple environmental impact categories. The baseline product was also quantitatively compared to product variations which included different materials, modified processes, or different product disposal options. The products analyzed by the student teams during this semester were:

- 1) Cork wine bottle stoppers and comparison to polymeric stoppers
- 2) Nylon versus steel railcar bearings
- 3) Wooden toothpicks and comparison to polymeric toothpicks
- 4) Plastic detergent jugs and comparisons of various disposal/recycling schemes
- 5) Nylon versus polyester automobile seat belts
- 6) Leather wallets with various materials and features

Because all of the life cycles phases of these products were considered, the student knowledge from different disciplines was important for a thorough analysis. Generally, mechanical engineering students were able to comment on mechanical design and processing. Industrial systems engineers had insights into manufacturing processes, logistics, and transportation. Chemical and materials engineers provided detailed understanding of the materials and chemical processes required for these products. The civil/environmental engineering students were able to relate the outputs from the products and processes to environmental effects.

Even simple products, like those above, selected by the student teams are complex to model thoroughly, so the LCA software was critical for the quantitative analysis; the size of the team allowed good coverage for all aspects of the product. The students were required to identify their specific roles within the team, complete the analysis, and present the analysis in report format as well as a 20 minute presentation to the class. To encourage teamwork within the multidisciplinary project, the assessment of the students was based on several components. 40% of the project grade was given to the project team as a whole for the written report and oral presentation, 40% of the grade was based on the individual roles that the students assigned themselves on their team, and 20% of the grade was based on the students' peer assessment of the contributions of the other members of their team.

### **Assessment Methods**

A pre- and post-course survey was used in this class to understand the baseline for the incoming students' understanding of LCA concepts and to help assess degree to which the learning objectives were met. Data collection for the pre-course survey was conducted anonymously using paper questionnaires, filled out by students during the first class meeting. The post-course survey was completed electronically, in accordance to the University's Honor Code, and submitted through email by all except one respondent who chose to complete a paper questionnaire. Since surveys were completed anonymously, pre- and post-test scores are compared in aggregate. To encourage participation, students were given bonus points equivalent to a single quiz for completing the post-course survey without regard for the accuracy of their answers. The 2006 pre- and post-course surveys are included in the appendix.

Identical questions covering several of the course learning objectives were included on both the pre- and post-course surveys to assess gains in student understanding in these topics. For example, question 5 on the pre-course survey, "*List the 4 main phases of the life cycle of a product,*" links directly to course learning objective 1, "*Identify the 4 phases of the life cycle of a product, process, or system.*" The learning objectives and survey instruments are included in the appendix as reference. In addition to the cognitive domain learning questions, the pre-course survey also included an affective domain question on student motivation for taking this particular

course. Additional affective domain questions on the post-course survey included questions relating to homework, reading, etc. and reflective questions about the course and personal impact. According to Bloom's Taxonomy, cognitive questions test knowledge and mental skills, whereas affective questions ask about attitudes, feelings, and emotions.<sup>7</sup>

The responses on the pre- and post-course surveys were compiled and analyzed as follows. For the LCA content questions, a mini-rubric was developed to quantify the accuracy of the responses. For example, question 5 (listing phases of the life cycle) was scored as one point for each correct phase, for a maximum of 4 points. Other questions (#3, 4, 10) were scored on a 0 to 4 scale ranging from a 0 for "no understanding" to a 4 for "excellent understanding." The course instructor scored these cognitive domain questions. Affective domain questions were coded by a research assistant. Ten categories were created for coding pre-course question 1, open-ended student motivation for taking this course, using an open coding procedure from qualitative research.<sup>8</sup> Other affective domain questions were a combination of 10-point Likert scale and open response. However, the positive end of the scale was undefined, so the text responses were used to recode numerical responses so that 10 was positive.

While the multidisciplinary team aspects were of interest to the primary instructor of this course, they were not initially considered carefully in terms of assessment. As is often the case when faculty begin to consider assessment for a new class, the focus was predominantly on the content. As the course progressed, however, it was apparent that multidisciplinary skill building was complex and would not just happen spontaneously. For these reasons, the assessment in this area for the course is neither as detailed nor as quantitative. As discussed further below, subsequent versions of this course will focus much more on the multidisciplinary nature of the course and team project, and less on the specific course content.

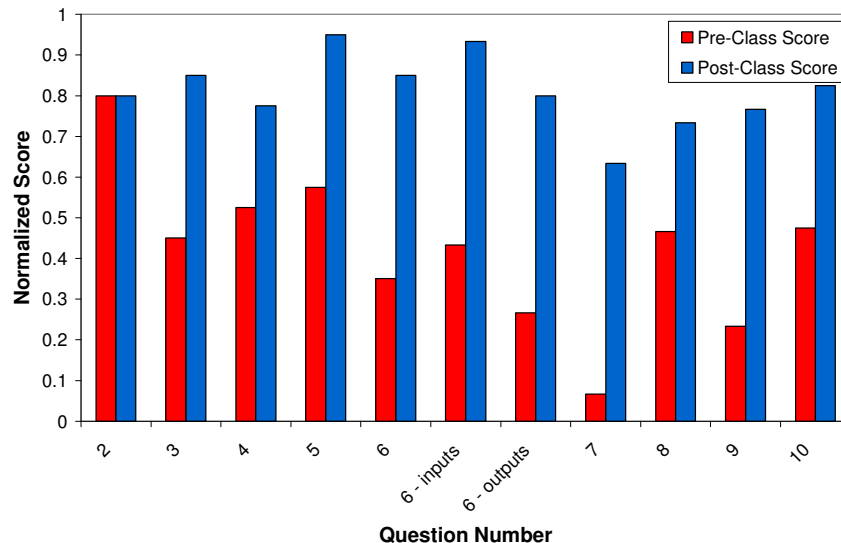
## Results

***Cognitive Question Analysis.*** Averages and standard deviations of the responses were computed for the cognitive survey question scores, and these are listed in Table 1. Due to the anonymous pre-course survey, an unpaired t-test was performed on the data to examine for significant statistical differences in the responses to the pre- and post-course surveys. From the t-test results, all questions except for the question on the importance of green engineering (#2) show a statistically-significant gain ( $p < 0.01$ ) in the students' understanding of the material. Figure 1 displays the normalized score of these cognitive questions of the survey; the normalized values were computed by dividing the average score by total possible points for the question. Note that question 6, which asked for both inputs and outputs, was further divided to show specific improvements between common inputs and outputs used in a life cycle analysis.

**Table 1:** Summary of the coded responses to pre- and post-course survey questions linked to course learning objectives, including statistical data of average score, standard deviation, and the p-value.

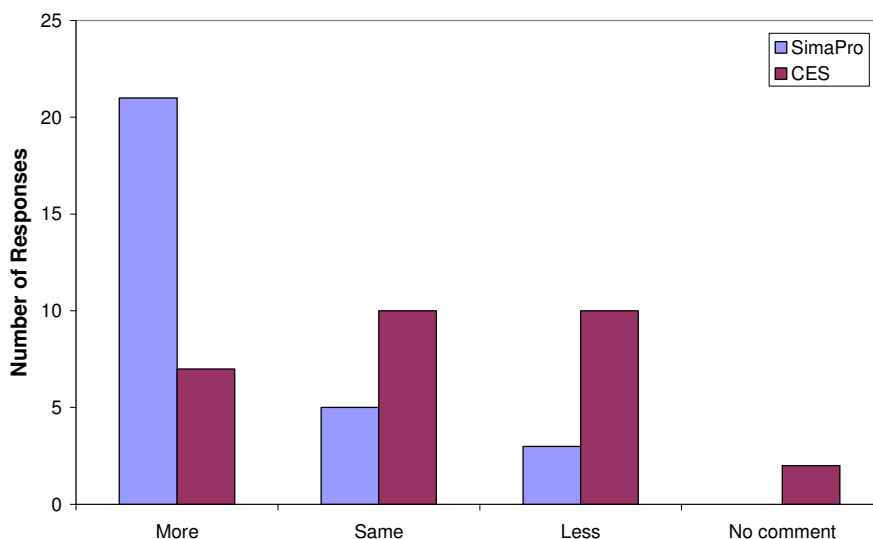
Pre-Course Survey #	Coding Scale	Question Verbiage	Average		Standard Deviation		t-test
			Pre	Post	Pre	Post	p-value
2	0 - 3	List 3 reasons why engineers should be concerned about the environmental impact of their professional decisions	2.4	2.4	0.67	0.57	0.616
3	0 - 4	Describe in a few sentences your current understanding of the general concept of Environmental Life Cycle Assessment Methodology (What is it? Why do it? What does one do? What does it provide?)	1.8	3.4	1.3	0.63	<0.001
4	0 - 4	Explain in a few sentences why engineers should perform LCA on products, processes, and systems	2.1	3.1	1.0	0.82	<0.001
5	0 - 4	List the 4 main phases of the life cycle of a product	2.3	3.8	1.1	0.76	<0.001
6	0 - 6	List 3 common inputs and 3 common outputs for products or processes that would be used in an LCA	2.1	5.1	2.1	1.25	<0.001
6 - inputs	0 - 3	List 3 common inputs for products or processes that would be used in an LCA	1.3	2.8	1.3	0.64	<0.001
6 - outputs	0 - 3	List 3 common outputs for products or processes that would be used in an LCA	0.8	2.4	1.0	0.82	<0.001
7	0 - 6	List any 3 major environmental impact categories and describe one or more potential endpoints	0.4	3.8	0.7	1.70	<0.001
8	0 - 3	List 3 specific sources for quantitative environmental data (more specific than “on the web”)	1.4	2.2	1.0	0.51	<0.001
9	0 - 3	List 3 limitations of current Life Cycle Analysis methods	0.7	2.3	0.9	0.70	<0.001
10	0 - 4	Discuss in a few sentences why product design is a critical phase in the life cycle of a product	1.9	3.3	1.0	0.65	<0.001

**Affective Questions Analysis.** Pre-course survey question 1 revealed student motivation for taking the course. While this is a core class for the 18-credit Green Engineering Concentration, less than half of the students in the class (15/33) were pursuing the concentration. Other common motivations for students were fulfillment of an engineering-science graduation elective, general concern for the environment, or interest from the course description.



**Figure 1:** Normalized values of the average scores of the questions linked to course learning objectives on the pre- and post-course surveys.

In addition to the identical LCA content questions from the pre-course survey, the post-course survey included a number of affective, reflective questions. Asked for the “*degree to which you would recommend this class to other students in your discipline*”, 66% students reported “highly” while the other 10 responses “moderately”. Based on 29 responses, the overall rating for the class on a scale of 1 (poor) – 10 (excellent) ranged from 6 to 9 with an average of 8. With regard to the use of the software packages in the class, the survey asked students to “*indicate whether you think the class should spend more, less, or the same amount of time on the CES software and SimaPro LCA software.*” The data in the Figure 2 indicates that students feel that more time is needed for the LCA software while the same or less time is needed for CES.



**Figure 2:** Responses regarding amount of time spent on two software packages used in the class.

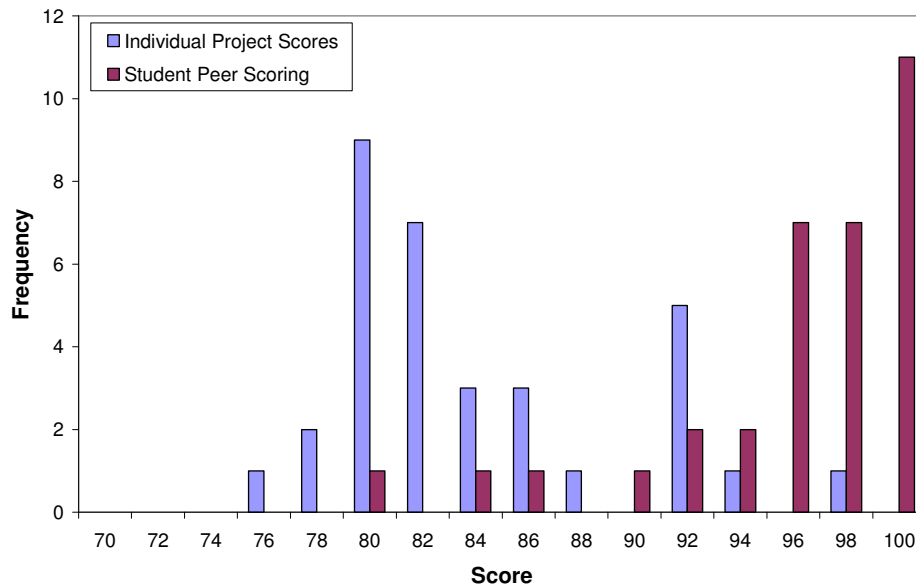


Post-survey question 9 asked the students “*Did you find the individual material/product presentations interesting and useful? Would you recommend these again or use the class time for other topics?*” While all of the responses on the interest and usefulness of these assignments was positive, the length of time required for the class presentation was noted in about 25% of the responses.

**Team Project Analysis.** For the multidisciplinary team project, the scores, which serve as one potential assessment tool, are shown in Table 2 and Figure 3. Table 2 is the overall project score earned by team. Figure 3 shows the scores based on the individual student contributions compared to the average peer rating of each student by the others in his/her team. The average for the individual scores was 83 while that for the peer average ratings was 95.

**Table 2:** Team Project Scores

Team	Score
1	83
2	85
3	92
4	82
5	84
6	98
Average	87



**Figure 3:** Individual student scores compared to the average students peer ratings on the team project

These data and analyses provide an objective framework through which to consider the effectiveness of the class in meeting the stated learning objectives.

## Discussion

The pre-course survey was initially viewed as simply a means to probe the students' knowledge in this topic area as they started the course from a variety of different disciplinary backgrounds. As the course proceeded, the instructor realized that a post-course survey using the same content questions could allow statistical analysis of the learning gains in these areas. As mentioned previously, assessment of the multidisciplinary aspects of the course were not adequately considered in these surveys.

The responses to the survey content questions indicate that significant gains in understanding concepts of Environmental LCA were made with the exception of the question concerning "*why engineers should be concerned about the environmental impact of their professional decisions.*" Since the average rating for this question was 2.4 on a scale of 0 – 3, it is likely that the students came into the class with a good grasp of this issue. For all questions except for question 7 concerning environmental impacts and potential endpoints, the normalized final scores are above 70%. These scores suggest that, in general, the instruction method was effective in meeting the learning objectives represented by the survey questions. While more emphasis should be placed on question 7 to increase the end learning level (63.3%), the normalized learning gain from pre- to post-course survey was one of the highest (56.7%) and the pre-course understanding was the lowest among the cognitive questions (6.7%)

The use of the software within the class did prove challenging. The amount of time required to review the software to the point it could be used by the students was underestimated. This was particularly the case for the SimaPro LCA software, which required the students to work through various tutorials and examples to learn the basics. The students were strongly encouraged to spend time on the tutorials early in the semester to prepare for application of the software for the team project. Discussions with the teams indicated issues in effectively using the software. Based on this experience and survey results which confirmed that more time was needed for the LCA software, the CES software will not be used in 2007; the time saved will be used to focus on the LCA software, especially through examples. Although the CES software was considered useful by many of the students, it is indirectly related to LCA through the environmentally conscious materials selection and design. Other interdisciplinary or disciplinary courses on product design should be considered for use of the CES software.

Overall, the quality of the multidisciplinary student projects was good as indicated by the team scores. In terms of individual contribution, there was a broad distribution among the students. Since the team average (87) was higher than the individual averages (83), one effect of the teams was to improve the overall project quality. It is also interesting to note that the peer assessments were extremely positive with an average and distribution skewed well above 90/100. In fact, the most probable score for the peer average rating was the 98 - 100 range, indicating that students felt their teammates put in maximal effort. However, it is important to note that none of these project scores provide a clear assessment of the multidisciplinary team skills acquired by the students in these projects. In fact, in several cases it was clear from discussions with the students or from the written reports that the students worked primarily as individuals and simply collated their sections together for the final report. In these cases, the grading scheme was not enough to encourage anything beyond the minimum amount of multidisciplinary work that the teams

considered acceptable. Although improvement of interdisciplinary team skills was a goal for the instructors of this class, it was not explicitly stated in the learning objectives. A more carefully considered approach to foster the desired multidisciplinary skills as well as to properly assess them is a goal for this class. One approach to move in this direction for the 2007 class is to set up the expectation that all team members must be familiar with all key aspects of the project and then to question individual team members in areas outside their assigned roles.

Despite the overall successes of the course, analysis of the survey responses also indicates that the surveys needed to be more specific to ensure usable data. Many of the questions were open-ended, creating a wide range of responses which were difficult to use in formal assessment. Prompts have been created for several of the course learning objective questions to help clarify the question as well as simplify scoring. Vague question wording from the 2006 surveys was improved for the 2007 versions; 2006 pre-course question 2, "List 3 reasons why engineers should be concerned about the environmental impact of their professional decisions" became the more specific question of "List 3 specific examples of how engineering practice can have adverse environmental impacts," number 3 on the 2007 pre-course survey. The modified 2007 surveys are included in the appendix.

The Likert rating scale was improved for the affective questions of the 2007 post-course survey. In the 2006 survey, the 1 to 10 scale was poorly defined, thus creating some confusion for students and the investigators. When coding these answers, particular attention to the student comments had to be read to ensure the students answered using the same rating scale. Additionally, a method to code the surveys to track specific improvements in an individual student's pre- and post-course survey will be used. With a coding system, a paired t-test can be performed on the data to provide additional information. For example, information about the student's major might be linked to the surveys to find correlations between responses and the specific major.

In addition to the above changes to the surveys, we wanted to develop a method to code the surveys for analyzing the pre- and post-scores through a paired t-test and still protect students' anonymity. The students were asked to write a 4 digit code they would remember for the rest of the semester, for example the last 4 digits of their parents' phone number or 4 digits of a former address. If students completed the Introduction to Green Engineering course, they indicated this by placing a "G" at the end of the code. To correlate information about majors and how the disciplinary score differed on the pre- and post-surveys, the instructor has also requested the students to include the abbreviation for the major the student is pursuing. A graduate student is compiling and scoring the surveys, thus the instructor cannot associate survey answers with students in underrepresented majors until after grades are assigned for the semester.

To gain some insight into how the students work on the group project, the instructor has decided to hold team interviews for the spring semester 2007. This interview will directly affect the team's grade on the project. Additionally, a graduate student doing research in multi- and interdisciplinary teamwork will observe and interview some of the student teams for the spring semester 2007. The instructor will not know which teams volunteers for observations and/or interviews. Since graduate student is disassociated with grading the students, these observations will not influence the final project grades, but insights into how the teams perform and

suggestions for improving teamwork will be offered after the graduate student has compiled his findings.

## **Conclusion**

We end with recommendations for others assessing multidisciplinary courses based on our experience in this class:

1. Assessment is an important tool for identifying strengths and weaknesses in the course structure. In our case, the data demonstrated a statistically significant improvement in the learning for most of the cognitive questions related to learning objectives, but individual questions could have no gain or a significant gain to a level still below that desired. This information can be used to target specific areas for future improvements.
2. Questions should be sufficiently detailed to avoid ambiguity. This question 2, as well as many others, became more focused in the revised surveys for 2007. Additional improvements, such as answer prompts, were created to lessen student confusion and ease investigator scoring.

The Likert scales of the affective questions have also been restructured to improve reliability of the students' responses. Students will be able to circle the ranking matching their opinion, with the option to comment. The ratings have been tailored to the question, thus avoiding ambiguity such as using "extremely" to rate the amount of homework in the course.

3. Assessments in the form of simple pre- and post-course surveys can provide evidence to support changes to improve the course. For this course, the general impression of the instructor was that software packages used in the class could be used more effectively was confirmed by the student responses. Moreover, the responses assisted in the decision regarding how to change the software use for subsequent classes.
4. If multidisciplinary team skills are truly desired as an outcome, they should be explicitly stated as course objectives to highlight their importance. Accurate assessment of these skills demonstrated by the students also requires more than self-reported surveys or grading schemes that might appear on the surface to encourage multidisciplinary engagement.

## **Bibliography**

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<sup>3</sup>Criteria for Accrediting Engineering Programs: Effective for Evaluations During the 2006-2007 Accreditation Cycle, ABET Engineering Accreditation Commission, www.abet.org, Oct. 2005.

<sup>4</sup>Living Planet Report 2006, World Wildlife Fund, 2006.  
*[http://assets.panda.org/downloads/living\\_planet\\_report.pdf](http://assets.panda.org/downloads/living_planet_report.pdf)*

<sup>5</sup>CES Selector, version 4.6, Granta Design Limited, 2005.

<sup>6</sup>SimaPro 7, version 7.0, Pre Consultants, 2006.

<sup>7</sup><http://www.nwlink.com/~donclark/hrd/bloom.html>, Accessed January 17, 2007.

<sup>8</sup>Patton, M. Q. *Qualitative Research & Evaluation Methods*, Thousand Oaks: Sage Publications, 2002.

# Appendix

## **Course Learning Objectives:**

Having successfully completed this course, the student will be able to:

1. Identify the 4 phases of the life cycle of a product, process, or system
2. Understand the critical role of materials selection in the design
3. Understand the origin and meaning of data used to quantify environmental impact
4. Describe why Life Cycle Analysis (LCA) is a critical skill for engineers in terms of technical, economical, societal, environmental, and political impacts
5. List major environmental impact categories and explain potential endpoints
6. Identify the 4 steps for completing a life cycle analysis
7. Draw an LCA system boundary and identify key inputs and outputs
8. Understand the limitations of LCA and discuss why this type of analysis is valuable in spite of the shortcomings
9. Find sources of environmental impact data and critically analyze the quality of that data
10. Perform a simple LCA on a product, process, or system using a spreadsheet or commercial software
11. Understand the concept of “weighting” in LCA analysis and interpretation
12. Make basic recommendations, based on materials selection and LCA analysis, to minimize the environmental impact of a product, process, or system
13. Understand how product design and LCA are can be used together to minimize environmental impact.

## **Grading:**

Quizzes	25 %
Homework	40 %
Major Project	35 %
– 40% group effort (written report/oral presentation)	
– 40% individual effort from responsibilities defined by your project scope document	
– 20% project teammates’ rating of your effort and contribution	

## ENGR 3134 Tentative Outline\*

Spring Semester, 2006

- |      |   |                       |
|------|---|-----------------------|
| I.   | <i>Introduction</i>                                       | <i>Week 1</i>         |
|      | A. Product Life Cycle                                     |                       |
|      | B. Life Cycle Analysis                                    |                       |
|      | C. Environmental Impacts                                  |                       |
| II.  | <i>Product Life Cycle, Materials Selection and Design</i> | <i>Week 2 - 7</i>     |
|      | A. Extraction   |                       |
|      | B. Manufacturing/Processing                               |                       |
|      | C. Packaging  |                       |
|      | D. Transportation/Distribution                            |                       |
|      | E. Use  |                       |
|      | F. End-of-Life/Recycling/Landfill/Incineration            |                       |
|      | G. Materials Selection                                    |                       |
|      | H. Product Design   |                       |
|      | I. Process Design   |                       |
|      | J. Design for Environment                                 | <i>Spring Break</i>   |
| III. | <i>Life Cycle Analysis</i>                                | <i>Week 8 - 15</i>    |
|      | A. Life Cycle Analysis Framework                          |                       |
|      | B. Life Cycle methods and software                        |                       |
|      | C. Inventory Analysis                                     |                       |
|      | D. Impact Assessment                                      |                       |
|      | E. Data location and integrity                            |                       |
|      | F. Sensitivity Analysis                                   |                       |
|      | G. LCA interpretation                                     |                       |
|      | H. LCA Weighting  |                       |
|      | I. LCA Limitations  |                       |
|      | J. Life Cycle Cost Analysis                               | <i>As time allows</i> |
|      | K. Six Sigma, Lean Manufacturing                          | <i>As time allows</i> |
|      | L. Project Presentations                                  |                       |

**\*Note - this outline is a general roadmap of the topics that we plan to cover in this course. The actual path taken and time spent on these topics will vary as we work our way through them.**

**ENGR 3134 – Environmental Life Cycle Analysis  
2006 Pre-Class Survey**

1. Explain in a few sentences why you are taking this class?
2. List 3 reasons why engineers should be concerned about the environmental impact of their professional decisions.
3. Describe in a few sentences your current understanding of the general concept of Environmental Life Cycle Assessment Methodology (what is it, why do it, what does one do, what does it provide?)
4. Explain in a few sentences why engineers should perform LCA on products, processes, and systems
5. List the 4 main phases of the life cycle of a product
6. List 3 common inputs and 3 common outputs for products or processes that would be used in an LCA
7. List any 3 major environmental impact categories and describe one or more potential endpoints
8. List 3 specific sources for quantitative environmental data (more specific than “on the web”)
9. List 3 limitations of current Life Cycle Analysis methods
10. Discuss in a few sentences why product design is a critical phase in the life cycle of a product

**ENGR 3134 – Environmental Life Cycle Analysis  
2006 Post-Class Survey**

1. Circle the degree to which you would recommend this class to other students in your discipline:

*Highly*                      *Moderately*   *Neutral*                      *Weakly*                      *Not at all*

Explain why you would recommend the course at the level indicated.

2. What do you think are the most and/or least useful parts of this class? Indicate topics that you would add, remove, or change the level of emphasis.
3. Briefly comment on how the concept of product/process design presented in this class is different from other classes you have taken which discuss design.



4. Rate this class overall on scale of 1 – 10 compared to others in terms of learning and usefulness. Provide any comments if you'd like to clarify your answer.
5. Rate the amount of homework in this class on a scale of 1 – 10. Provide any comments if you'd like to clarify your answer.
6. Rate the difficulty of homework, quizzes, project on a scale of 1 – 10. Provide any comments if you'd like to clarify your answer.
7. Rate the amount and quality of the reading material on a scale of 1 – 10. Provide any comments if you'd like to clarify your answer.
8. Indicate whether you think the class should spend more, less, or the same amount of time on the CES software and SimaPro LCA software. Explain briefly.
9. Did you find the individual material/product presentations interesting and useful? Would you recommend these again or use the class time for other topics?
10. What do you think will be the biggest impact of this class on your future?
11. Please provide any other comments which you think could improve the class for next year.
12. List 3 reasons why engineers should be concerned about the environmental impact of their professional decisions.
13. Describe in a few sentences the general concept of Environmental Life Cycle Assessment.
14. Explain in a few sentences why engineers should perform LCA on products, processes, and systems
15. List the 4 main phases of the life cycle of a product
16. List 3 common inputs and 3 common outputs for products or processes that would be used in an LCA
17. List any 3 major environmental impact categories and describe one or more potential associated endpoints
18. List 3 specific sources for quantitative environmental data (more specific than “on the web”)
19. List 3 limitations of current Life Cycle Analysis methods
20. Discuss in a few sentences why product design is a critical phase in the life cycle of a product

**ENGR 3134 – Environmental Life Cycle Analysis**  
**2007 Pre-Class Survey:**

1. Why you are taking this class? (check all that apply)

- required for the Green Engineering concentration
- fulfills an Engineering Science elective
- co-op/internship revealed industry movement towards Green Engineering
- interest in the course from the course description
- concern about the environment and/or environmental issues
- possibly pursuing Green Engineering in/as a career
- foresee value beyond graduation
- résumé builder
- diversifying education
- gaining a different perspective of engineering
- other:

2. Which one of the following best describes your feeling about the concern for the environment in the design and manufacturing of products, processes, and systems?

- Performance and cost should be the key design criteria followed by environmental issues to the extent that they do not significantly affect the former and no environmental rules or regulations are violated.
- The environment should be considered equally along with cost and performance in the design of a product
- Given potentially serious environmental risks, these issues should be the primary factor in product design and weighted more heavily than cost and performance
- Other:

**The remainder of the questions relate to your current understanding of Environmental Life Cycle Assessment concepts and methodology.**

3. List 3 specific examples of how engineering practice can have adverse environmental impacts
4. Describe 3 benefits of Life Cycle Analysis for engineering products, processes, or systems
5. Describe 3 limitations for using Life Cycle Analysis for engineering products, processes, or systems
6. List the 4 steps to completing a Life Cycle Analysis

7. List 2 advantages and 2 disadvantages of using stream-lined LCA compared to full LCA
8. List the 4 main phases of the life cycle of a product, process, or system
9. List 3 common inputs and 3 common outputs for products or processes that would be included in an LCA
10. List any 3 major environmental impact categories along with a potential midpoint and endpoint associated with each category
11. List 3 specific sources, one from each general category, where you can find quantitative environmental data
  - 1) Websites:
  - 2) Government Agencies:
  - 3) Software/Databases:
12. List 3 risks for not considering the environment in the design stage for a product, process, or system

**ENGR 3134 – Environmental Life Cycle Analysis  
2007 Post-Class Survey**

**Note that the results of this survey may be used for research purposes, but all responses will be anonymous. You will receive points for every serious answer you provide.**

1. Circle the degree to which you would recommend this class to other students in your discipline:

*Highly      Moderately      Neutral      Weakly      Not at all*

Explain why you would recommend the course at the level indicated.

2. Indicate your thoughts concerning the level of coverage in the class on the topics below by placing a check in the appropriate boxes. Do not consider the relative importance of the topics, rather whether the amount of time and depth in each area was appropriate to helping you learn and apply critical concepts in these areas.

Topic	Need a lot more focus	Need little more focus	About right	Need a little less focus	Need a lot less focus
Extraction					
Manufacturing					
Use					
Disposal					
Materials Selection					
Environmental Impacts					
LCA methodology					
SimaPro LCA Software					
Sources for LCA data					
Streamlined LCA methods					
Use of LCA in design					

3. Briefly comment on how the concept of product/process design presented in this class is different from other classes you have taken which discuss design.

4. Rate this class overall compared to others in terms of learning and usefulness. Provide any comments if you'd like to clarify your answer.

High – good    Mid – good    Low – good    Low – bad    Mid – bad    High – bad

5. Rate the amount of homework in this class. Provide any comments if you'd like to clarify your answer.

Much more than necessary    A lot more than necessary    Little more than necessary    Little less than necessary    A lot less than necessary    Much less than necessary

6. Rate the difficulty of homework. Provide any comments if you'd like to clarify your answer.

Extremely difficult    Moderately difficult    Slightly difficult    Slightly easy    Moderately easy    Extremely easy

7. Rate the difficulty of quizzes. Provide any comments if you'd like to clarify your answer.

Extremely difficult    Moderately difficult    Slightly difficult    Slightly easy    Moderately easy    Extremely easy

8. Rate the difficulty of the project. Provide any comments if you'd like to clarify your answer.

Extremely difficult	Moderately difficult	Slightly difficult	Slightly easy	Moderately easy	Extremely easy
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9. Rate the amount of the reading material. Provide any comments if you'd like to clarify your answer.

Much more than necessary	A lot more than necessary	Little more than necessary	Little less than necessary	A lot less than necessary	Much less than necessary
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10. How useful was the supplemental reading material in helping you learn the class concepts by providing another perspective. Provide any comments if you'd like to clarify your answer.

High – good	Mid – good	Low – good	Low – bad	Mid – bad	High – bad
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11. Please provide any other comments which you think could improve the class for next year.

12. Which one of the following best describes your feeling about the concern for the environment in the design and manufacturing of products, processes, and systems?

*Performance and cost should be the key design criteria followed by environmental issues to the extent that they do not significantly affect the former and no environmental rules or regulations are violated.*

*The environment should be considered equally along with cost and performance in the design of a product*

*Given potentially serious environmental risks, these issues should be the primary factor in product design and weighted more heavily than cost and performance*

*Other:*

**The remainder of the questions relate to your current understanding of Environmental Life Cycle Assessment concepts and methodology.**

13. List 3 specific examples of how engineering practice can have adverse environmental impacts

14. Describe 3 benefits of Life Cycle Analysis for engineering products, processes, or systems

15. Describe 3 limitations for using Life Cycle Analysis for engineering products, processes, or systems

16. List the 4 steps to completing a Life Cycle Analysis

17. List 2 advantages and 2 disadvantages of using stream-lined LCA compared to full LCA
18. List the 4 main phases of the life cycle of a product, process, or system
19. List 3 common inputs and 3 common outputs for products or processes that would be included in an LCA
20. List any 3 major environmental impact categories along with a potential midpoint and endpoint associated with each category
21. List 3 specific sources, one from each general category, where you can find quantitative environmental data
  - 1) Websites:
  - 2) Government Agencies:
  - 3) Software/Databases:
22. List 3 risks for not considering the environment in the design stage for a product, process, or system