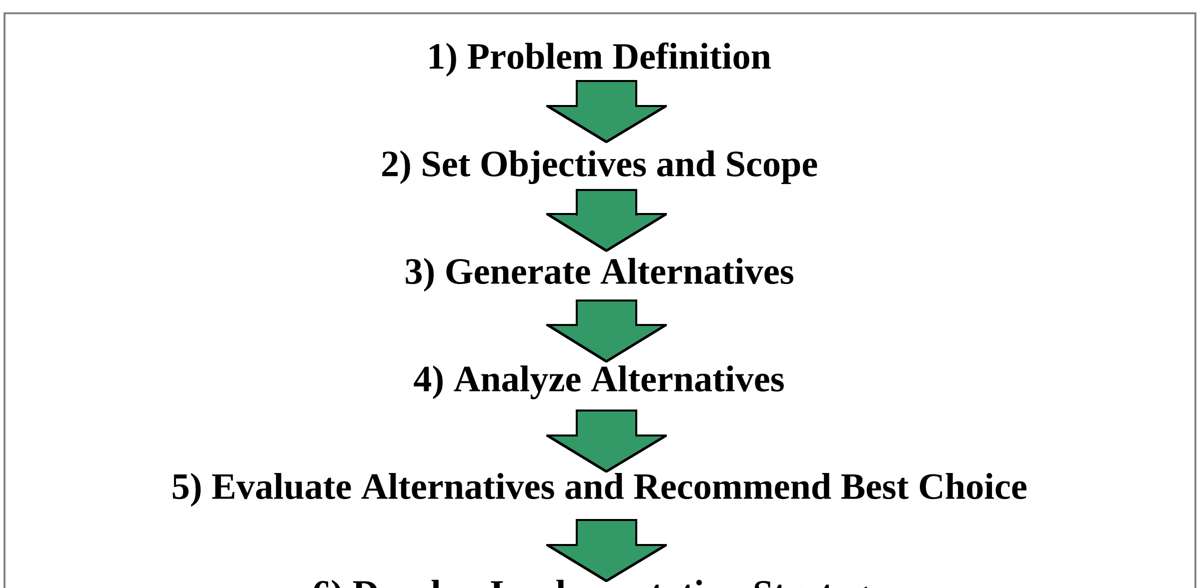
GE Series Course 4

In 1996, a fourth GE-sponsored course was offered within the School of Civil and Environmental Engineering. This course, the Sustainable Problem Solving Laboratory, was supervised by Dr. Jorge Vanegas, Associate Professor, School of Civil and Environmental Engineering. The course was co-developed and co-taught by Jennifer DuBose, Research Associate with the Center for Sustainable Technology; and Annie Pearce, Ph.D. Candidate, School of Civil and Environmental Engineering. 15 students participated in the pilot offering of the course during Summer Quarter 1996. The course integrated the instructors' expertise in context-based policy development and implementation, sustainability, and engineering problem solving and design. The students in the course were primarily seniors in Georgia Tech's School of Civil and Environmental Engineering who were interested in the concept of sustainability and wished to apply it to design problems as part of the engineering design requirements for their degree program.

The primary objective of the course was to provide students with a structured process for formulating, solving, and implementing solutions to engineering problems while incorporating the often-qualitative objectives of sustainability. Figure 1 shows a representation of the six-step problem solving process used to structure the class. Other learning objectives for the laboratory were to familiarize students with the concept of sustainability and its ramifications for design, decision making, problem solving, and engineering; to develop skills for interfacing with the public and presenting design recommendations; to strengthen written and oral communication skills; and to strengthen problem-solving skills, working both individually or in groups.

Figure 1: The Six-Step Problem Solving Process



solving process introduced throughout the course as students progressed with their individual projects. The first two class sessions were used to assist students in selecting project topics and scoping the projects to a manageable level that could be completed in a single quarter. A mandatory individual meeting of each student with the instructors was required at the problem scoping phase to assist each student in defining a manageable problem to be solved. Students were encouraged to choose a problem by answering the question, “What irritates or inspires you most?” All problems chosen by the students were from the “real world” of engineering, and required interfacing with practitioners and members of the community outside the university.

Lectures, assigned readings, and in-class exercises provided the means for introducing students to the six steps of the problem solving process and allowed them to practice each step in the context of their self-selected engineering problems. The course provided a forum for developing professional written and oral communication skills by requiring a formal project report and presentation to be delivered to the instructors, who acted as mock “clients” of the student engineers “hired” to solve their specific problems. Guidelines for the final project report and presentation were provided to the students (see Appendix D-1) to link each step of the problem solving process to the problem investigated by each student. Students were encouraged to submit drafts of each section of the final report to the instructors for review and comment after each step of the problem-solving process was covered in the lecture. An electronic mailing list was established for the course to encourage students to post progress reports and interact outside of class to learn from the experiences of their classmates. The instructors also provided prompt written feedback on all interim submissions, and provided office hours by appointment to provide individual help as necessary.

Lectures 1 and 2, *Introduction* and *Finding Problems to Address,* introduced the students to the concept of sustainability, used examples of existing artifacts to show how design decisions have implications beyond the artifact being designed, and helped students to identify potential problems to be addressed in their term projects. Assigned readings for these classes included "Principles of Sustainable Development" (PCSD 1994), "Sustainable Technologies for the Building Construction Industry" (Vanegas et al. 1995), "Canon on Sustainability is Justified" (Veltrop 1995), and "A Compass for Sustainable Development" (Robert et al. 1996), to introduce the students to sustainability concepts in the context of civil and environmental engineering. Class exercises included interactive exercises on design critique for disposable beverage containers, and problem framing using an example of grocery bags. Students were required to submit short essays describing their answers to the question, "Who are you, and why do you care about sustainability?"

The next two lectures covered the topic of *Problem Definition*. In these lectures, videos and class discussions were used to introduce ideas for researching the problem, asking the right question, documenting information, establishing the context of the problem, identifying relevant issues, defining problem scope, working with people, and setting objectives and weightings. Assigned readings included selected portions of *Ecological Design* (Van der Ryn & Cowan 1996) and *Audubon House: Building the Environmentally Responsible, Energy-Efficient Office* (National Audubon Society 1994), to illustrate the kinds of objectives typically considered in sustainable engineering projects as well as the implications of context on selecting appropriate objectives. During this week, students were required to post brief descriptions of their proposed project topics to the course usenet group. Students also scheduled individual meetings with the instructors to discuss their proposed topics and to scope the projects to a level that could be completed for a single term project. Following these lectures, students were required to submit a draft of the first part of their final project report describing the scope and objectives of their term solving their selected problems. In-class exercises included a drawing exercise to help students tap the creativity of their non-dominant brain hemisphere, small group brainstorming of solutions for student projects, and a video showing innovative solutions for Design for Disassembly used by the Daimler-Benz company. These lectures introduced students to seeing all sides of the problem, the affordances of designed artifacts, brainstorming techniques, systems thinking, and established strategies for industrial ecology, design for disassembly, and regenerative design. The purpose of class exercises and readings for these lectures was to help students "think outside the box" and be non-critical of seemingly outrageous solutions which might hold promise for their term projects. Readings included selected portions of *Breakthrough Thinking* (Nadler & Hibino 1990), *Regenerative Design* (Lyle 1994), and "Industrial Ecology: Concepts and Approaches" (Jelinski et al. 1992). Following these lectures, the students each submitted a draft of the second part of their final project report describing the alternatives generated during brainstorming for solutions to their problems.

The seventh and eighth lectures, *Analyzing Alternatives,* provided an overview of existing engineering analysis methods relating to sustainability, including environmental impact assessment, life cycle analysis, feasibility determination, cost-benefit analysis, contingent valuation, and other metrics and criteria for sustainable design. Lectures were supplemented by a video on Life Cycle Costing for Built Facilities and an in-class debate on the price of life. Readings included selected portions of *Environmental Impact Assessment* (Jain et al. 1994), "Resource and Environmental Profile Analysis" (Hunt et al. 1992), "The History of a Cup of Coffee" and "An Order of French Fries" (Durning & Ayres 1994, 1995), "Changing Course: An Outline of Strategies for a Sustainable Future" (Corson 1994), and "Assessing Sustainability Projects" (AtKisson & LaFond 1994). Following these lectures, students submitted preliminary analyses of a selected set of feasible alternatives that they planned to consider for their term projects. These submissions constituted a first draft of the third portion of their final project report.

The ninth and tenth lectures, *Evaluating Alternatives,* provided a basis for helping students to systematically select solutions for their problems based on how well each considered alternative met the initial objectives for their problems. In these lectures, students revisited the initial sustainability and engineering objectives for their problems, and learned how to combine qualitative and quantitative information to comparatively evaluate each alternative solution. Guest lecturers from professional practice also provided discussion and information on how to present results to clients and the public, make recommendations, and target the appropriate audience for their engineering recommendations. In-class exercises in constructing objectives matrices demonstrated various methods for comparing alternatives. Assigned readings included "Pulling the Pieces Together: Amalgamation in Environmental Impact Assessment" (Elliott 1981), "Improving the Use of Information in Environmental Decision Making" (O'Hare 1980), and *Some Tips on Report Writing* (Reddy 1992). These readings demonstrated approaches for combining qualitative and quantitative information, as well as providing guidance for preparing and delivering the results of engineering analysis to clients and the general public. Following these lectures, students submitted drafts of their evaluation of potential solutions and recommended alternatives, comprising the first draft of the fourth portion of their final project reports.

Lecture 11, *Implementation Issues,* covered the topics of working within organizational constraints, developing implementation strategies, creating an implementation plan, and including and interfacing with the public. This lecture built on the topics introduced in lectures nine and ten, and introduced students to work breakdowns, cost and resource estimating, and other issues associated with implementing solutions to engineering problems. Assigned readings included "Strategic approach to transportation project implementation" (Lloyd & Meyer 1984), and selected portions of *Environmental* plan for their recommended solution.

The next two class sessions were used for student presentations of the results of their term projects. The class was provided with anonymous sheets to rate each presenter and to provide comments about presentation content and delivery. The final class session, *Wrap-up: Summary and Conclusions,* helped to tie the course together by answering the questions, "How has sustainability changed problem solving?", "What remains to be done?", and "What does the future hold?". This lecture also included student evaluations of the course content and delivery, and served as a forum for discussion and finding answers to last-minute project-related questions. The final project report from each student was due during the week following the last class period. Table 1 shows the titles and a brief summary of the 15 student projects for the pilot course.

The students were required to submit their final reports in a format appropriate for a design portfolio, so that they could build their own portfolio in preparation for professional engineering practice. In two cases, the student reports were actually delivered to stakeholders in the real world and used in developing solutions. This course, while not a part of the original three-part series in sustainability, served as a focused forum for one discipline within the College of Engineering to further integrate the concept of sustainability into its curriculum. Student comments and long-term feedback about the course emphasized both the difficulty of solving problems with a fuzzy objective like sustainability, as well as the usefulness of having a structured problem solving process in developing sustainable solutions.