An Engineering Undergraduate/Graduate Course on Sustainable Design and Construction

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Abstract: Sustainable development challenges institutions at every level, from global to local, to create new avenues for the development, design, production, marketing, delivery, and disposal of products, goods, and services, and for the use of natural resources. At the basis of the vision of sustainable development is a new paradigm of economic growth in harmony with the environment, which requires the education of engineers, technological professionals, and decision/policy makers with an integrated view of technologies and their applications, and sensitivity to the complexity and diversity of the cultural, natural, and societal environment.

As a direct response to this challenge and need, the Georgia Institute of Technology implemented in recent years an institute-wide multi-disciplinary curriculum development effort for sustainable development and technology, funded by the GE Fund and the National Science Foundation. Building on the results of this initiative, faculty in the Construction Engineering and Management (CEM) Program in the School of Civil and Environmental Engineering (CEE) at GT has been developing and teaching, over the last six years, a course for undergraduate and graduate students on Sustainable Design and Construction. This course focuses on preparing the future generation of civil engineers, and more specifically, of construction engineering and management professionals, to work toward achieving Built Environment Sustainability (BES). This paper provides a description of the evolution and current status of this course, and of the lessons learned.

1.0 Introduction

Sustainable development challenges institutions at every level, from global to local, to create new avenues for the development, design, production, marketing, delivery, and disposal of products, goods, and services, and for the use of natural resources. At the basis of the vision of sustainable development is a new paradigm of economic growth in harmony with the environment, which requires the education of engineers, technological professionals, and decision/policy makers with an integrated view of technologies and their applications, and sensitivity to the complexity and diversity of the cultural, natural, and societal environment. Consequently, engineering education must instill in its students an early respect and ethical awareness for sustainable development, including an understanding and appreciation of cultural and social characteristics and differences among various world communities. In addition, students need to acquire the analytical tools to assess risks and impacts, to perform life cycle analyses, and to solve technical problems, cognizant of and taking into consideration the economic, socio–political and environmental implications.

In 1993, the *American Association of Engineering Societies* (AAES) suggested a conceptual framework for the role of engineers in sustainable development based on six principles (AAES 1993). First, engineers must be trained and engaged more actively in political, economic, technical and social discussions and processes to help set a new direction for the world and its development. Second, engineers need to use environmentally sensitive and responsive economic tools, in order to integrate environment and social conditions into market economics. Third, in planning for sustainable economic development, engineering should become a unifying, not a partitioning, discipline. Engineers need to look at systems as a whole, as opposed to looking at fragmented or single parts. Fourth, engineers and scientists must work together to adapt existing technologies and create and disseminate new technologies that will facilitate the practice of sustainable engineering, meet societal needs, improve resource use (including energy resources) and minimize waste generation. Fifth, the

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knowledge, skills and insights of the physical as well as the social sciences, together with all engineering disciplines must be brought together in a new collaborative partnership. Finally, engineers must cultivate an understanding of environmental issues, problems, risks and potential impacts of what they do.

As a direct response to the need to educate a new generation of engineers within the principles of sustainable development, the Georgia Institute of Technology (GT) implemented in recent years an institute-wide multi-disciplinary curriculum development effort for sustainable development and technology, funded by the GE Fund and the National Science Foundation (Chameau et al. 1998; McElvaney and Vanegas 1998; Vanegas 1995). Over 20 faculty members, representing Engineering, Computing, Science, Architecture, Public Policy, and Management, participated directly in this initiative over a period of five years, and many of them continued their work after the completion of the project. Figure 1 shows the overall framework that guided the curriculum development effort.

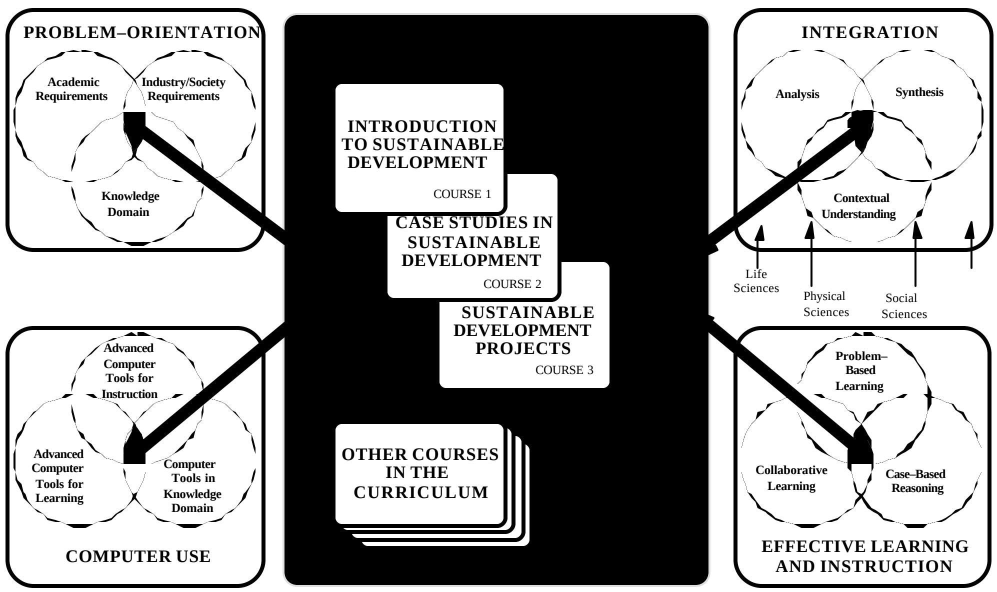

Figure 1: Conceptual Framework for Curriculum Development (Vanegas 1995)

The long–term objective of this curriculum development effort was to educate engineers who understand the relationship between technology and the environment, and who will be leaders in applying technology to achieve environmentally–compatible gains in economic development. The short–term objectives of this curriculum development effort were to: (1) Provide a multi– and inter–disciplinary learning environment that incorporates the latest advances in cognitive science and computer–aided instruction and learning, to produce engineers who are environmentally–conscious and view development and economic growth in a global, international context; (2) Introduce major curricular changes, not only in the way courses are designed and developed, but more importantly, in the way students learn and are taught within a problem–based, case–based and collaborative learning and reasoning environment, and the way they develop and strengthen their integrative skills in analysis, synthesis and contextual understanding of real–world problems; (3) Address the academic, industry and societal requirements of sustainable development, within a global marketplace perspective, and expose students to the latest technologies in different engineering fields and the implications for sustainability of their use; (4) Enable students to become more involved in the transfer of engineering knowledge and experience, both as initial recipients of this knowledge, and later as creators and disseminators of new knowledge and experience; and (5) Enable engineers to become environmental leaders and decision makers, not just technical advisors, i.e., become more proactive in formally incorporating environmental planning at all stages of individual projects, and especially in evaluating the long–term and aggregate impact of their design decisions at each stage.

Three courses formed the core of the curriculum. These courses were taught several times by inter-disciplinary teams to engineering and non-engineering students.

- The first course, *Introduction to Sustainable Development,* provided students with an understanding of fundamental concepts of sustainability and an awareness of their implications for engineering practice. It introduced them to the context and characteristics of sustainability, and allowed them to: (1) Explore the technological, social, environmental and economic dimensions of sustainability; (2) Examine the ways in which sustainability impacts engineering: and (3) Be exposed to different strategies and mechanisms for sustainability.
- The second course, *Case Studies in Sustainable Development,* provided students with a view of how the sustainability of engineering systems can be improved based on a number of situational case studies. It exposed students to the: (1) Investigation of sustainability in practice; (2) Inclusion of sustainability considerations in engineering; (3) Enhancement of sustainability by design; (4) Chemicals in the environment; (5) Long and short term safety and health hazards; and (6) Technical, economical, ecological and ethical considerations and trade-offs
- The third course, *Design of Open and Sustainable Engineering Systems,* provided students with the opportunity to deepen their understanding of sustainability by undertaking a design project. The focus of the course was learning how to design in a sustainable manner orchestrated by using a project involving the redesign of a system to ensure sustainability, which addressed: (1) Market economics and culture; (2) Availability of resources such as energy, material, information, and capital; (3) Technology availability, maturity, methods and models; and (4) Society, public policy, values, motivation, and politics. Specific topics discussed in the course included: definition of sustainable systems; methods of identifying and selecting sustainable solutions to design problems; methods of making trade-offs between alternative solutions and methods of improving existing solutions; using statistics in modelling decisions; and learning through reasoning.

The original intent of the curriculum development initiative was to use these three courses as a laboratory to understand the various dimensions of sustainability within the context of engineering education, and to identify associated pedagogical issues. Once the project was completed, the goal was to incorporate sustainability as an integral component of the standard engineering curricula of the various schools of engineering, not as a separate track or sub-specialty. Consequently, these three courses were phased out. Today, sustainability is addressed within many courses across all colleges at GT. The Institute for Sustainable Development and Technology (ISTD) at GT maintains an on-going compilation of the multiple and diverse sustainability-related courses and other academic and research initiatives (http://www.istd.gatech.edu).

Building on the results of the overall curriculum development initiative, and on the specific experience gained in these courses, the Construction Engineering and Management (CEM) Program in the School of Civil and Environmental Engineering (CEE) at GT has been developing and teaching, over the last six years, a course for undergraduate and graduate students on Sustainable Design and Construction. This course focuses on preparing the future generation of civil engineers, and more specifically, of construction engineering and management professionals, to work toward achieving Built Environment Sustainability (BES). This paper provides a description of the evolution and current status of this course, and of the lessons learned.

2.0 Sustainable Problem Solving Laboratory

The initial point of departure for the CEM/CEE/GT course was a fourth course offered to undergraduate students within the GE/NSF sponsored curriculum development initiative. This course, *Sustainable Problem Solving Laboratory*, provided students with a structured process for formulating, solving, and implementing solutions to engineering problems while incorporating the often-qualitative objectives of sustainability. The learning objectives for the laboratory were to: (1) Familiarize students with the concept of sustainability and its ramifications for design, decision making, problem solving, and engineering; (2) Develop skills for interfacing with the public and presenting design recommendations; (3) Strengthen written and oral communication skills; and (4) Strengthen problem-solving skills, working both individually or in groups

The course was structured around individual student projects executed throughout a ten-week term, using a six-step problem solving process, shown in Figure 2.

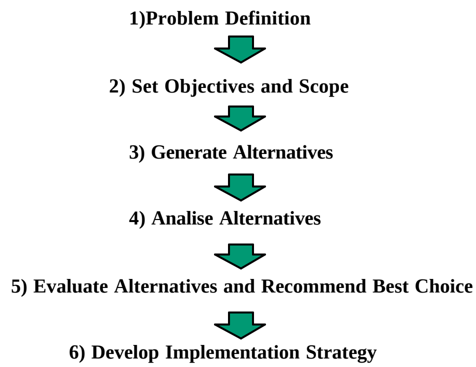

Figure 2: Conceptual Framework for Curriculum Development

Lectures, assigned readings, and in-class exercises provided the means for introducing students to the six steps of the problem solving process, which were introduced sequentially as the students progressed with their individual projects. This approach allowed them to practice each step in the context of their self-selected engineering problems. The initial part of the course was used to assist students in selecting project topics and developing a manageable scope of work, which could be completed within the duration of the course. 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 that the students interact with practitioners and members of the community outside the university.

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 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.

The specific content of the course was:

- The first two lectures, *Introduction* and *Finding Problems to Address*, introduced the students to the concept of sustainability, used examples of existing artefacts to show how design decisions have implications beyond the artefact 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.
- 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.
- The next two lectures focused on introducing students to methods for *Generating Alternatives* for 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 affordance of designed artefacts, 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).

- The next two lectures focused on *Analysing Alternatives,* and 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).
- The next two lectures focused on *Evaluating Alternatives*, and 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.
- The next lecture, *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 Impact Assessment* (Jain et al. 1994), to provide examples and recommendations for implementing solutions and to introduce strategies for overcoming common barriers to successful implementation.
- 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. Finally, the last class session, *Wrap-up: Summary and Conclusions*, helped to tie the course together by answering three questions: (1) *How has sustainability changed problem solving?* (2) *What remains to be done?* and (3) *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 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, CEE, to further integrate the concept of sustainability into the 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. Additional information on the results of this course can be found at http://maven.gtri.gatech.edu/sfi/conted/conted.html.

3.0 Environmentally Conscious Design and Construction

The next iteration of the CEM/CEE/GT course was a graduate course, *Environmentally Conscious Design and Construction*, which built upon the approach, materials, and lessons learned from the first version of the course. This course provided students with an introduction to the strategies, analysis methods, and processes of environmentally conscious planning, design, construction, operation, deconstruction, and assessment of built facilities, and presented a systematic framework for problem solv ing, decision-making, and design using the principles of sustainability as guiding objectives. Tools, methods, and techniques for gathering information, generating, analysing, and evaluating alternatives, and developing implementation strategies will be presented and demonstrated. Course activities included a combination of lectures, in-class discussions and exercises, and several out-of-class group and individual and team assignments and a team project. Table 1 contains a synthesis of the topics covered in the course.

Table 1: Course Topics

1. Sustainability and the Built Environment: o Properties of the Built Environment o What is Sustainabilit y? o Systems Theory and Analysis o Thermodynamic Foundations	***2. Designing an Analysis Strategy:*** o Qualitative Measurement and Scale Construction o Threats to Validity o Documentation and Record-keeping o Data Collection Methods o Interdisciplinary Teaming o Multimedia Documentation o Systems Analysis o Impact Mapping and Assessment
3. Facility Assessment Methods: o Sampling and Demographics o Measurement Theory	***4. Ecosystem Impact Assessment:*** o Ecosystem Classification Methods o Site-related Strategies
5. Resource Base Impact Assessment: o Mass Balance and Flow Analysis Methods o Recap of Problem Framing	***6. Component Assessment Methods:*** o Indicator Methods of Measurement o Structured Selection Processes
7. Sustainability and the Built Environment: o Properties of the Built Environment o What is Sustainability? o Systems Theory and Analysis o Thermodynamic Foundations	***8. Designing an Analysis Strategy:*** o Qualitative Measurement and Scale Construction o Threats to Validity o Documentation and Record-keeping o Data Collection Methods o Interdisciplinary Teaming o Multimedia Documentation o Systems Analysis o Impact Mapping and Assessment
9. Facility Assessment Methods: o Sampling and Demographics o Measurement Theory	***10. Ecosystem Impact Assessment:*** o Ecosystem Classification Methods o Site-related Strategies
11. Resource Base Impact Assessment: o Mass Balance and Flow Analysis Methods o Recap of Problem Framing	***12. Component Assessment Methods:*** o Indicator Methods of Measurement o Structured Selection Processes
13. The LEED Building Rating System	***14. Energy-Related Strategies:*** o Power Demand Management o Equipment Efficiency o Building Shell Improvements o Passive Design Strategies o Alternative and Renewable Energy Systems

Table 1: Course Topics (continued)

15. *Water-related Strategies:* o Demand Management o Rainwater Harvesting o Regenerative Design o Wastewater Management and Recovery o Storm water Management	**16. *Materials-related Strategies:*** o Alternative Material Substitution o Resources for Sustainable Materials o Pollution Prevention o Material Efficiency o Material Recovery, Reuse, Recycling
17. *User-oriented Strategies:* o Indoor Air Quality o EMF o Acoustics and Lighting o Design for Adaptability o Promoting Sustainable Behaviour o Community Context o Wastewater Management and Recovery o Stormwater Management	**18. *Implementation Planning:*** o Logistics o Assessing Organizational Resources and Requirements
19. *Strategy Integration:* o Whole System Comparison and Evaluation o Lovins' Discontinuity Principle	**20. *Life Cycle Analysis:*** o Evaluating Performance Criteria o Economic Cost-Benefit Analysis o Projecting Future System Behaviours o Qualitative Cost-Benefit Analysis
21. *Communication and Delivery of Results:* o Targeting the Appropriate Audience o Presenting Results and Supporting Recommendations	**22. *Becoming an Agent of Change:*** o Surmounting Organizational Barriers o Environmental Enterprise in the Construction Industry

The principal educational objectives of the course were to: (1) Familiarize students with the concept of sustainability as it applies to the built environment, and its ramifications for design, decision making, and construction practice; (2) Introduce students to a general approach for solving problems, and show how it can be applied to real world problems; (3) Acquaint students with the principal theories, materials, and construction techniques used to create environmentally conscious buildings or retrofit existing buildings to be more sustainable; (4) Develop specific skills for interfacing with the public and presenting design recommendations; (5) Develop a set of feasible solutions for a real world problem; (6) Strengthen written and oral communication and presentation skills; and (7) Strengthen problem–solving skills, working both individually and in groups.

Upon completion of this course, students were expected to: (1) Identify a range of feasible and contextually appropriate actions for improving the sustainability of a built facility through multiple phases of its life cycle; (2) Compare these actions in terms of their relative performance according to traditional qualitative and quantitative criteria such as first- and life cycle cost, time, and quality; (3) Compare these actions in terms of their relative impacts on the facility's sustainability; (4) Design a recommended course of action to increase the sustainability of the facility, and plan its implementation; and (5) Support their recommendations with convincing evidence and well-organized analysis, delivered in a professional fashion. Table 2 contains a synthesis of the assignments in the course, designed to support these learning objectives.

Table 2: Course Assignments

ASSIGNMENT	SKILL DEVELOPMENT	EXECUTION
Experimental Observation Project	Experiment Design & Execution Impact Monitoring Documentation	Individual • Lab report • Journal
Building Material/System Comparative Analysis	Problem framing & definition Data collection & analysis Professional Interaction Multimedia Communication	Individual • Supporting documentation • Display • Informal briefing

Table 2: Course Assignments (continued)

ASSIGNMENT	SKILL DEVELOPMENT	EXECUTION
LEED Assessment of a Building	Data Collection and Analysis Documentation Multimedia Communication Supported Argument/Persuasion	Combined Small Group • Supporting documentation • Display components • Formal briefing
Design of a Sustainability Improvement Plan	Team skills Solution integration Comparative analysis Problem solving Multimedia Communication Process documentation Supported Argument/Persuasion	Interdisciplinary Group (3-4 people) • Formal report • Formal briefing • Process analysis • Supporting material (models, displays, etc.)

4.0 Sustainable Design and Construction

The current version of the CEM/CEE/GT course is a graduate course, *Sustainable Design and Construction*, which is open to selected undergraduate students who have an interest, a good record of academic performance. The course builds upon the approach and lessons learned from the courses described in Section 2.0 and Section 3.0, bringing together the structure and approach of the first course, with the content and material covered in the second. It incorporates, as reference material, most of the readings and materials used and developed for these two courses, in addition to other resources such as web links to available on-line material.

The course continues to provide an introduction to the strategies, analysis methods, and processes of assessment, planning, design, construction, operation, deconstruction, for sustainable built facilities, and to present a systematic framework for problem solving, decision making, and design using the principles of sustainability as guiding objectives. Tools, methods, and techniques for gathering information, generating, analysing, and evaluating alternatives, and developing implementation strategies are presented and demonstrated. Course activities include a combination of lectures, in-class discussions and exercises, and several out-of-class group and individual laboratories, and a semester-long team project.

The principal teaching objectives for the course are to (1) familiarize students with the concept of sustainability as it applies to the built environment, and its ramifications for planning, design, and construction practice; (2) introduce students to a general approach for solving problems and making decisions, and show how they can be applied to the development of a set of feasible solutions for real world problems; and (3) acquaint students with the principal theories, materials, and construction techniques used to create sustainable buildings or to retrofit existing buildings to be more sustainable.

By the end of the course, students are expected to be able to (1) identify feasible and contextually appropriate actions for improving the sustainability of a facility through multiple phases of its life cycle; (2) compare these actions in terms of their relative performance according to traditional qualitative and quantitative criteria such as cost, time, and quality, and also, of their relative impacts on the facility's sustainability, according to criteria such as contextual compatibility and response, resource base impact, eco-system impact, and human satisfaction; (3) design a recommended course of action to increase the sustainability of the facility; and (4) plan its implementation.

There are two main differences between this course and its previous versions:

- The first difference is that this course uses a formal textbook, "*Sustainable Practices: Development and Construction in an Environmental Age"* (Langston and Ding 2001). The textbook provides the knowledge base for a series of formal debates on selected topics between student teams in the following topic areas; Environmental Quality; Development Controls; Analytical Tools; Project Feasibility; Design Considerations; Energy Conservation; Life Cost Studies; Asset Management. Formal debates have proven to be a very effective learning mechanism.
- The second difference is the scope of the semester-long team project. The focus of the project is the development of "*A Blueprint for Sustainable Communities*" for disadvantaged/underprivileged

communities in developing countries. Each student team is assigned a different problem domain within the community as the focus of their efforts: Energy System; Water Supply System, Wastewater System; Stormwater System; Solid Waste System; Residential Facilities; Community Facilities; Commercial Facilities; Recreational Facilities and Open Areas; and Socio-economic Development. Student teams work independently, and when necessary, they interact with each other. At the end of the term, the complete set of projects provides a cohesive whole. This type of project has also proven to be a very effective learning mechanism.

5.0 Conclusions

More than ever before, students enter engineering programs with a built-in environmental and social consciousness. Incoming students have a better understanding of the problems faced by our earth, and a better grasp of the technologies available to solve them. Engineering educators should take advantage of this awareness and motivation, and equip students with the knowledge and skills needed to find effective solutions to present and future problems. Providing students with a forum for learning the skills they need and a place to express their solutions in the real world is one way to help create better engineers for the future. Empowering our students to make a difference while they are still students will provide them with the confidence and experience they need to aggressively address problems they encounter in professional practice.

Teaching sustainability within the context of CEM/CEE is similar to traditional engineering education since it requires helping students: (1) Understand the complexity of real world problem solving, and learn how to apply theoretical engineering knowledge in real world contexts; (2) Develop critical thinking skills; (3) Make links to the skills and knowledge they already have; (4) Learn how to work well in teams of their peers of the same discipline; and (5) Develop exemplary written and oral communication skills.

However, as a result of the complexity of this knowledge domain, teaching sustainability within the context of CEM/CEE is different to traditional engineering education since it requires helping students: (1) "*Unlearn*" reductionism in their approach to problem solving; (2) Expand the scope of considerations for a given problem; (3) Be able to better structure and document decisions, and manage greater quantities of information; (4) Be comfortable with qualitative types of data, and with merging the qualitative and quantitative in solving problems; (5) Generate and analyze non-traditional solutions to problems; thinking outside the box; (6) Pay attention to context; develop context-specific, customized solutions to problems; (7) Work with <u>all</u> stakeholders in a project, and work well in inter- or multi-disciplinary teams.

Finally, five specific needs emerge from the lessons learned from these courses. To successfully teach sustainability:

- There is a need to "*Walk the Talk*"; once students are exposed to sustainability, they become very aware of "unsustainable" behaviours surrounding them, especially from the instructor.
- There is a need to create an organizational environment that supports sustainability.
- There is a need to for better teamwork and integration, on both sides of the lectern.
- There is a need to provide links to "*Real World*" problems.
- There is a need to use project-based learning and other innovative learning strategies.

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