An Engineering Undergraduate/Graduate Course on Sustainable Design and Construction

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Collaboration

- This paper presents the results of a collaboration between:
  - The Construction Engineering and Management Program (CEM), of the School of Civil and Environmental Engineering (CEE), of the College of Engineering (COE), at the Georgia Institute of Technology (GT)
  - The Sustainable Facilities and Infrastructure Branch (SFI), of the Safety, Health, and Environmental Technology Division (SHETD), of the Electro-optics, Environment, and Materials Laboratory (EOEML), of the Georgia Tech Research Institute (GTRI)

Introduction

Challenges of Sustainable Development

- SD is a new paradigm of economic growth in harmony with the environment
- SD challenges institutions to create new avenues for:
  - development, design, production, marketing, delivery, and disposal of products, goods, and services
  - use of natural resources
- SD requires the education of engineers, technological professionals, and decision/policy makers with
  - an integrated view of technologies and their applications,
  - sensitivity to the complexity and diversity of the cultural, natural, and societal environment

Role of Engineers in Sustainable Development

- ***American Association of Engineering Societies*** (AAES) suggests six principles:
  - 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.
  - Engineers need to use environmentally sensitive and responsive economic tools, in order to integrate environment and social conditions into market economics.
  - 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.

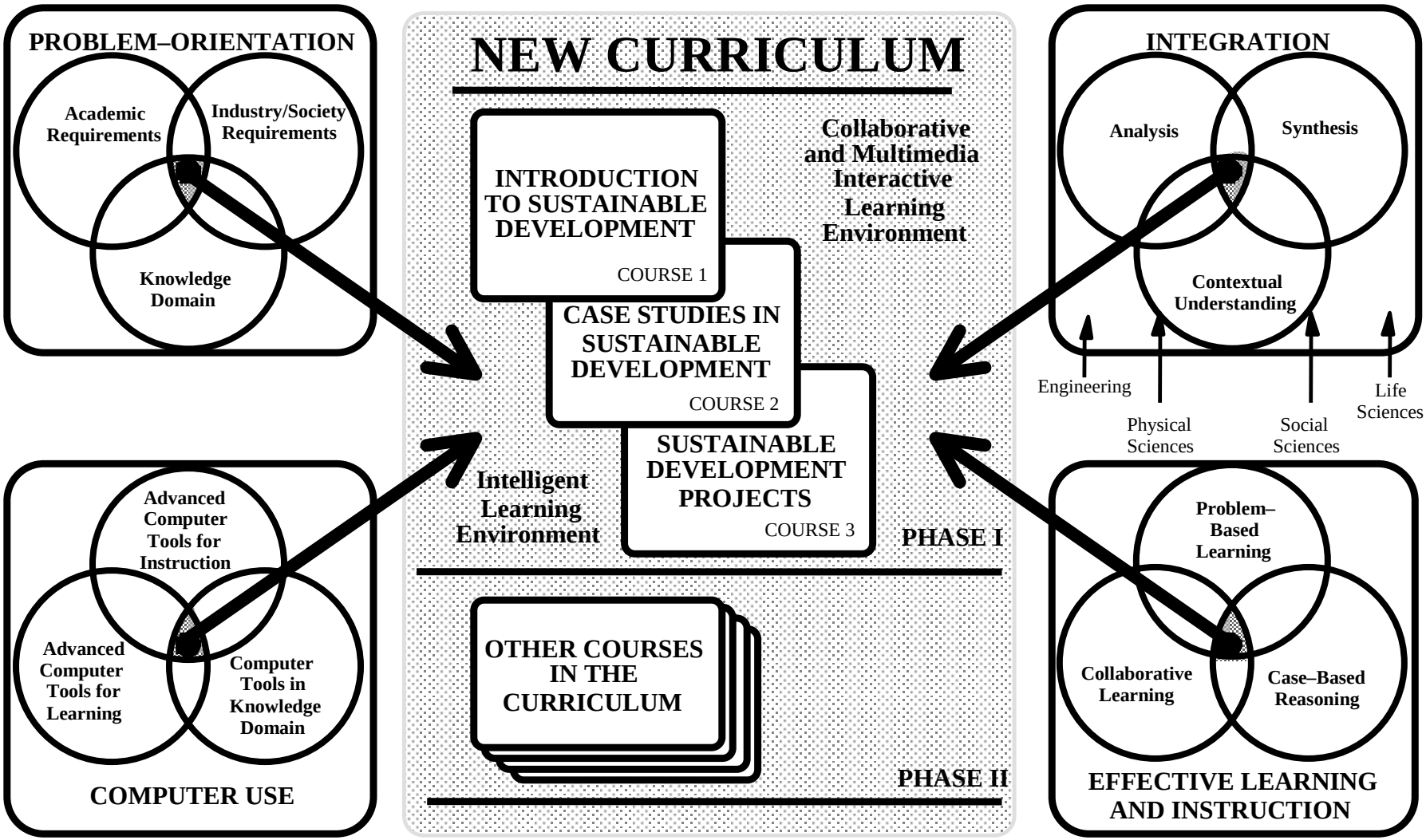
Role of Engineers in Sustainable Development (cont.)

- AAES principles (cont.):
  - 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.
  - The 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.
  - Engineers must cultivate an understanding of environmental issues, problems, risks and potential impacts of what they do

The Response from Georgia Tech

- From Vision...
  - To educate a new generation of engineers within the principles of sustainable development
- ...To Action
  - To implement an institute-wide multi-disciplinary curriculum development effort for sustainable development and technology
  - funded by the GE Fund and the National Science Foundation
- Over 20 faculty members, representing Engineering, Computing, Science, Architecture, Public Policy, and Management, among others participated in this effort

Conceptual Framework for Curriculum Development



Long-term Goals

- The long–term goal of this curriculum development effort was to educate engineers who understand the relationship between technology and the environment
- ...who are environmentally–conscious and view development and economic growth in a global, international context
- ... who will be leaders in applying technology to achieve environmentally–compatible gains in economic development

Short-term Objectives

- Provide a multi– and inter–disciplinary learning environment that incorporates the latest advances in:
  - Cognitive science
  - Computer–aided instruction and learning
- Introduce major curricular changes in the way:
  - Courses are designed and developed
  - Students learn and are taught within a problem–based, case–based and collaborative learning and reasoning environment
  - Students develop and strengthen their integrative skills in analysis, synthesis and contextual understanding of real–world problems

Short-term Objectives (cont.)

- Address the academic, industry and societal requirements of sustainable development, within a global marketplace perspective
- Expose students to the latest technologies in different engineering fields and the implications for sustainability of their use
- Enable students to become more involved in the transfer of engineering knowledge and experience:
  - As initial recipients of this knowledge
  - As creators and disseminators of new knowledge and experience
- Enable engineers to become environmental leaders and decision makers, not just technical advisors

Core Courses

- ***Introduction to Sustainable Development***, provided students with:
  - An understanding of fundamental concepts of sustainability and an awareness of their implications for engineering practice
  - Introduction to the context and characteristics of sustainability
- This course allowed them to:
  - Explore the technological, social, environmental and economic dimensions of sustainability
  - Examine the ways in which sustainability impacts engineering
  - Be exposed to different strategies and mechanisms for sustainability.

Core Courses (cont.)

- ***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:
  - Investigation of sustainability in practice
  - Inclusion of sustainability considerations in engineering
  - Enhancement of sustainability by design
  - Chemicals in the environment
  - Long and short term safety and health hazards
  - Technical, economical, ecological and ethical considerations and trade-offs

Core Courses (cont.)

- ***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 by using a project involving the redesign of a system to ensure sustainability, through:
  - Definition of sustainable systems
  - Methods of identifying and selecting sustainable solutions to design problems
  - Methods of making trade-offs between alternative solutions
  - Methods of improving existing solutions, using statistics in modelling decisions; and learning through reasoning

A Course on Sustainable Design and Construction

- Offered by CEM/CEE at GT for
  - Undergraduate students (as a technical elective)
  - Graduate students (as a required course)
- Builds on the results of the overall curriculum development initiative, and on the specific experience gained
- Has been in development over the last four years and taught in three versions:
  - Sustainable Problem Solving Laboratory
  - Environmentally Conscious Design and Construction
  - Sustainable Design and Construction

Sustainable Problem Solving Laboratory

Sustainable Problem Solving Laboratory

- This course 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:
  - Familiarize students with the concept of sustainability and its ramifications for design, decision making, problem solving, and engineering
  - Develop skills for interfacing with the public and presenting design recommendations
  - Strengthen written and oral communication skills
  - Strengthen problem-solving skills, working both individually or in groups

Sustainable Problem Solving Laboratory (cont.)

- 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:
  - Were self-selected engineering problem from the "*real world*" of engineering
  - Had a manageable scope of work, which could be completed within the duration of the course
  - Required that the students interact with practitioners and members of the community outside the university

Problem Solving Process

1)Problem Definition

2) Set Objectives and Scope

3) Generate Alternatives

4) Analyze Alternatives

5) Evaluate Alternatives and Recommend Best Choice

6) Develop Implementation Strategy

Environmentally Conscious Design and Construction

Environmentally Conscious Design and Construction Course

- This course 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,
  - 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 were presented and demonstrated.

Teaching Objectives
(from the instructor's perspective)

- Familiarize students with the concept of sustainability as it applies to the built environment, and its ramifications for design, decision making, and construction practice
- Introduce students to a general approach for solving problems, and show how it can be applied to real world problems
- Acquaint students with the principal theories, materials, and construction techniques used to create environmentally conscious buildings or retrofit existing buildings to be more sustainable

Teaching Objectives (cont.)
(from the instructor's perspective)

- Develop specific skills for interfacing with the public and presenting design recommendations
- Develop a set of feasible solutions for a real world problem
- Strengthen written and oral communication and presentation skills
- Strengthen problem–solving skills, working both individually and in groups

Learning Objectives

(from the student's perspective)

- Identify a range of feasible and contextually appropriate actions for improving the sustainability of a built facility through multiple phases of its life cycle
- Compare these actions in terms of their relative performance according to traditional qualitative and quantitative criteria
- Compare these actions in terms of their relative impacts on the facility's sustainability
- Design a recommended course of action to increase the sustainability of the facility, and plan its implementation
- Support their recommendations with convincing evidence and well-organized analysis, delivered in a professional fashion

Topics

- Sustainability and the Built Environment
- Designing an Analysis Strategy
- Facility Assessment Methods
- Ecosystem Impact Assessment
- Resource Base Impact Assessment
- Component Assessment Methods
- Sustainability and the Built Environment
- Designing an Analysis Strategy
- Facility Assessment Methods
- Ecosystem Impact Assessment
- Resource Base Impact Assessment

Topics (cont.)

- Component Assessment Methods
- The LEED Building Rating System
- Energy-Related Strategies
- Water-related Strategies
- Materials-related Strategies
- User-oriented Strategies
- Implementation Planning
- Strategy Integration
- Life Cycle Analysis
- Communication and Delivery of Results
- Becoming an Agent of Change

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
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.)

Sustainable Design and Construction

Sustainable Design and Construction

- Graduate course 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 two previous course iterations, bringing together:
  - the structure and approach of the first course
  - 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.

Differences with Previous Courses

- 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 between student teams, on selected topics:
  - Development Controls
  - Analytical Tools
  - Project Feasibility
  - Design Considerations
  - Energy Conservation
  - Life Cost Studies
  - Asset Management

Differences with Previous Courses (cont.)

- This course has semester-long team project:
  - development of "*A Blueprint for Sustainable Communities*" for disadvantaged/underprivileged communities in developing countries.
- Student teams address different problem domains:
  - Energy System
  - Water Supply, Wastewater, and Stormwater Systems
  - Solid Waste System
  - Residential, Commercial, and Community Facilities
  - Recreational Facilities and Open Areas
  - Socio-economic Development.
- At the end of the term, the complete set of projects provides a cohesive whole.

Conclusions

Conclusions

- Students enter engineering programs with:
  - A built-in environmental and social consciousness
  - A better understanding of the problems faced by our earth
  - 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
  - Provide students with a forum for learning the skills they need and a place to express their solutions in the real world
  - Empower students to make a difference while they are still students, giving them the confidence and experience they need to aggressively address problems they encounter in professional practice.

Conclusions (cont.)

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

Conclusions (cont.)

- Teaching sustainability within the context of CEM/CEE is different, since it requires helping students:
  - "*Unlearn*" reductionism in their approach to problem solving
  - Expand the scope of considerations for a given problem
  - Be able to better structure and document decisions, and manage greater quantities of
  - Be comfortable with qualitative types of data, and with merging the qualitative and quantitative in solving problems
  - Generate and analyze non-traditional solutions to problems; thinking outside the box
  - Pay attention to context; develop context-specific, customized solutions to problems
  - Work with <u>all</u> stakeholders in a project, and work well in inter- or multi-disciplinary teams.

Lessons Learned for Successfully Teaching 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.

Thank you!

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