An Education Program in Support of a Sustainable Future

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ABSTRACT
The historical evolution and current status of sustainability education at Michigan Technological University is described. The history considers the last 15 years, during which, the faculty of Michigan Tech have been collaborating on the development of environmental curricula and courses. This development effort initially focused on specialized offerings for the environmental/chemical engineering programs. With time, recognition of the importance of environmental issues (wastes, natural resources, energy, etc.) to other disciplines across the campus grew. For example, chemists, biologists, foresters, etc. each have a role in characterizing the behavior of ecological systems. Engineering disciplines that are focused on the design of products, processes, or systems influence long term societal sustainability. Social scientists must understand the relationships/linkages between the environment, industry, citizens, and government. Greener products, environmentally responsible processes, life cycle thinking, and environmental stewardship need to become part of the modern lexicon of globally aware students. Faculty from diverse disciplines across the campus are now collaborating to develop courses and modify curricula to educate students with respect to the triple bottom line (i.e., sustainable economic, societal, and environmental future). Problems associated with the traditional education paradigm are discussed. A new education model aimed at training students to create a sustainable future is proposed.

INTRODUCTION
Over the last few decades the world’s population has grown rapidly. In fact, for just 1987-1999, the population increased from five to six billion [1]. This rapid growth in numbers, in combination with per capita increase in resource use and economic activity, contributes directly or indirectly to serious societal and environmental problems. These problems will only increase over the next 50 years as the projected world population nears 12 billion and developing nations become more industrialized. Several years ago, former Wisconsin U.S. Senator Gaylord Nelson, who pioneered the creation of the first Earth Day in the United States in 1970, commented on the importance of the environment to our way of life. “In the jargon of the business world, the economy is a wholly owned subsidiary of the environment. All economic activity is dependent on the environment, and its underlying resource base. If the environment is finally forced to file under Chapter 11 because its resource base has been polluted, degraded, dissipated, and irretrievably compromised, then the economy goes bankrupt with it because the economy is just a subset within the ecological system” [2] Over the last several decades, more manufacturers have come to recognize the wisdom in Senator Nelson’s comments and have begun to enact fundamental changes in the way they operate with respect to the environment. Corporations have shifted away from waste treatment and remediation towards energy reduction and pollution/waste prevention. Corporations along with governmental agencies, citizens’ groups, foundations, and other non-governmental organizations (NGOs) are seeking new approaches for sustainable economic development and environmental quality. There is a growing awareness among manufacturers of the need to consider the triple bottom line (i.e. a sustainable
economic/industrial, societal, and environmental future), and that environmental challenges represent both business opportunities and a societal responsibility.

The growing recognition of the importance of achieving the triple bottom line has historically not been reflected in university educational programs. Rather, students are exclusively trained to be experts in their discipline. Mechanical and chemical engineering students are educated to design products and plan manufacturing processes based on performance and economics. These students give little consideration to potential societal and environmental consequences during design of such manufacturing processes. Business people are focused on quarterly profit statements and the bottom line, frequently with little regard to society or the world around them. Environmental engineers and scientists are typically focused on studying the treatment and environmental release of chemicals and rarely consider product design, manufacturing, and business issues. Similarly, social scientists and policy makers often make decisions that are poorly grounded from a technical standpoint. The segregated thinking of each of these individual disciplines leads to confusion, strife, and disagreement between parties and ultimately results in poor and unsustainable decisions.

Development along with environmental protection is now a goal broadly supported by government, industry, academia, and citizens. Sustainability is affected by decisions made by individuals, households, industry, organizations, and governmental agencies [3]. Significant progress has been made in recent years to improve the knowledge base for environmental decisions. In particular:

• Industrial Ecology and Ecological Economics, the study of resource use, and materials and energy flows through the economy, including associated pollutant emissions and valuation of ecosystem services;
• Multimedia environmental modeling, the study of geo- and bio-chemical processes that determine the fate and transport of chemicals through the environment; and
• Human perception and behavior, the study of the cognitive, social and economic factors that effect environmental decision making.

Significant contributions have been made in the education and research in each of these individual areas [3-8]. Yet there has not been an effort to develop the ability to conduct fully integrated research across these disciplines. For example, because industrial ecology was developed as a separate branch of study, it lacks the ability to analyze the effect of alternative policies, regulations, manufacturing decisions, etc. on consumer choice, resource utilization, pollutant emissions, human health, and other measures of sustainability that are of concern to individual stakeholders.

Education plays a major role in the way knowledge is used for sustainable development. Organizations are finding it more and more necessary to hire individuals with diverse skills: an awareness of community concerns, knowledge of political processes, familiarity with policy analysis, training in a scientific/engineering field, and an understanding of real-world decision making processes. As indicated above significant progress has been made in education and research in each of these individual areas. One of the roles of education/academia is to teach and conduct research on new ways so as to integrate the knowledge developed in different fields of study.

This paper presents the journey that Michigan Tech has taken to establish educational programs in support of sustainable development. It begins by laying out the history associated with multi-disciplinary environmental education at the University in several separate scientific and engineering disciplines. It then identifies some of the problems with this traditional approach. A new education paradigm is then described that addresses these problems. Additional comments on the role of education in creating an informed citizenry are also presented.

HISTORY OF ENVIRONMENTAL EDUCATION

Pollution Containment:

Civil engineering is a traditional discipline and has existed for many years at Michigan Tech. In the late 1980s an undergraduate environmental engineering program was established in connection with civil engineering. The environmental engineering program quickly became one of the largest in the U.S. and offered a traditional undergraduate curriculum that included such media focused courses as water resources system analysis, atmospheric chemistry, and environmental microbiology & chemistry. It also provided such pollution containment/control focused classes as environmental regulations, air quality engineering, and wastewater treatment. With time, environmental engineering M.S. and Ph.D. degree programs were also established. In general, most courses at both the undergraduate and graduate levels were focused on containing, controlling, and/or treating environmental wastes.
Of course, while environmental engineering is traditionally the repository for environment-related courses, even a decade ago many other programs also provided offerings. For example, the School of Forestry at MTU offered courses in natural resource policy, human dimensions of natural resources, and forest management; the Department of Chemical Engineering delivered courses in chemical process safety, pollution prevention, and remediation.

One example of a course created to promote pollution prevention is the Chemical Engineering class, “Chemical Process Safety/Environment”. The goal of this required course is to provide students with methodologies and software tools to design and evaluate chemical processes that are inherently safe and environmentally benign. This course prepares Chemical Engineers to incorporate safety and environmental assessments into their capstone senior design experience.

Environmental Engineering graduates, and to lesser extent students from Forestry and Chemical Engineering produced during this era formed what may be thought of as the first generation of environmental managers. These individuals received outstanding training in their discipline, but often had little insight into the true source of environmental wastes or into their role within the larger organization/system. For example, a water treatment engineer was very capable of addressing issues related to correcting a water pollution problem, but probably had little familiarity with the processes that polluted the water in the first place. As another example, a Forester might be comfortable in facing a citizen’s group and balancing competing organizational demands, but less prepared to work in or with public bureaucracies in solving problems of reforestation and natural resources.

Engineering for the Environment:

Building upon the success of the environmental engineering program at MTU, a campus-wide environmental thrust was established in the early 1990s. One of the outgrowths of this thrust was the establishment of a small cadre of faculty from across the College of Engineering that was concerned about environmental education issues. This group included individuals from mechanical, electrical, chemical, metallurgical, and environmental engineering. The group was focused on making students in all engineering disciplines aware of how their decisions influence the environment. Through a series of brainstorming workshops a course was established at the undergraduate level entitled “Engineering for the Environment.” This elective course emphasized pollution prevention concepts rather than pollution containment and was designed to serve all engineering disciplines. The class covered such topics as the flow of materials through an industrialized society, energy generation and distribution, the role of design and manufacturing in creating/preventing environmental wastes, environmental law, and environmental risk. A graphic repeatedly used throughout the course is displayed in Fig. 1.

Figure 1 displays the material life cycle of a product. The life cycle includes material and energy acquisition, material refinement, manufacturing, product use, product abandonment, waste treatment, and material disposal. Clockwise movement around the life cycle consumes time and energy, and also incurs costs (from individuals, corporations, and society). Also evident in the figure are inner loops associated with material recycling, remanufacturing, and reuse. The inner loops require progressively less raw material, energy, time, and cost, and are therefore preferred from a life cycle standpoint. This point of view was promulgated throughout the Engineering for the Environment course. Case studies employing LCA (life cycle analysis) and pollution prevention (P2) in order to reduce waste, pollutants and energy use [9, 10] were presented during the course.

![Figure 1: Life Cycle Stages of a Product [11]](image-url)
limited popularity of the course was due to the fact that the student curricula were simply too full to accommodate a class that would count only as a free elective. To address the popularity issue, Engineering for the Environment was repackaged as a set of senior technical electives cross-listed across multiple departments within the College of Engineering. This change significantly improved the popularity of the course offering.

After four offerings of the Engineering for the Environment class, industry asked us to deliver the course to them in graduate level form using distance-learning technology. The course was re-cast into a senior/graduate level version. To complement the course, a second class was created – Environmentally Conscious Design and Manufacturing (ECDM). This second course concentrated on how product and process design decisions influence environmental impact and the general concept of industrial ecology [12-15]. The second course built upon the first course and focused on where there is maximum opportunity for environmental improvement – the design of products and processes (refer to Fig. 2). The ECDM course considered such topics as design for disassembly, design for the environment, material flow, and material selection. Takeback issues and the logistics associated with product recovery and demanufacturing were also covered. In the area of environmentally responsible manufacturing [16, 17], the waste streams associated with a wide range of manufacturing processes were discussed (e.g., machining, welding, and casting).

Figure 2: Product Development Time Line

By the late 1990s, the two courses: Engineering for the Environment, and Environmentally Conscious Design and Manufacturing had served nearly 500 undergraduate and graduate students from Michigan Tech and our industrial partners. There were a number of successful aspects associated with this pair of courses. They did succeed in educating a number of non-environmental engineers on environmental issues, and in bringing to light the role of all engineers in minimizing environmental impact. The process of developing and delivering the two courses also helped to cultivate relationships between the participating faculty; this resulted in the added benefit that the group of faculty also began collaborating on research initiatives. But, the development of the two courses was not a complete success. The group failed to incorporate environmental issues into a course that was required of all engineering undergraduates. In addition, the two courses were lacking in terms of economic and social aspects. Simply designing green products, for example, does not guarantee environmental improvement since public participation/buy-in is required to motivate individuals to select greener products. Also, the understanding of waste generation is not only important in terms of production processes but also in terms of social, economic, and political processes.

Environmental Policy:

In parallel with the Engineering for the Environment initiative, an Environmental Policy program also developed at Michigan Tech. This program, housed in the Department of Social Sciences, emerged out of an undergraduate program in Science, Technology, and Society (STS). The STS program emphasized the importance of understanding the co-evolution of technology and society. Indeed, solving environmental problems today requires a broad range of expertise in science, technology, economics, politics, and social interactions. Increasingly, organizations find they need individuals with a diverse skill set including: awareness of local community and citizen concerns, knowledge of political processes in federal and state government, familiarity with social and policy analysis, training in a scientific field, and an understanding of technical solutions and limitations. Such a combination of skills and knowledge was not inculcated within traditionally trained environmental engineers or engineers benefiting from the two-course sequence: Engineering for the Environment, and Environmentally Conscious Design and Manufacturing.

Traditionally, environmental policy has focused on the use of regulatory strategies to remedy environmental problems. These regulations, shaped by professionals with a variety of legal, academic, and technical backgrounds, have been incrementally refined over the years. Early environmental policy programs, many of which evolved from public policy and public affairs programs, seldom offered training in the technical aspects of environmental problems. As a result, relatively little exchange occurred between professionals responsible for advances in
technology and those responsible for implementing and refining policy. Environmental policy programs also did not provide a full treatment of ethical, historical, and social analytical approaches to environmental problems.

Over the last several years, the Environmental Policy Program has significantly evolved. The M.S. degree offered through the program appeals to many undergraduate students in engineering/science that have a solid technical background. The aim of the program is to furnish students with training in complex organizational, industrial, and political issues. For those undergraduates with credentials in the social sciences, their graduate education must provide sufficient science and engineering training to deal effectively with the technical aspects of environmental problems. Various courses offered as a part of the program are

- Global Environmental Systems: Surveys the literature that connects global, biological, and physical processes with human adaptations and social systems.
- Environmental Policy and Politics: Examines environmental policy making and politics in the U.S. regarding air and water pollution, toxics, and hazardous wastes.
- Environmental Policy Analysis: Reviews major analytical tools (such as benefit-cost analysis and risk analysis) used at the federal, state, and local level.
- Sociology of the Environment: Applies basic sociological concepts to describe the relationship of humans to the environment.
- Environmental Decision Making: Examines the decision-making process associated with a local environmental concern or policy choice.
- Natural Resource and Environmental Economics: Economic analysis of pollution control decisions and use of market instruments for environmental protection.

In addition to serving the Environmental Policy program, each of these courses also attracts students from other graduate programs, including forestry, biology, humanities and business, environmental engineering, and mechanical engineering.

A NEW EDUCATION PARADIGM

The previous section provided a historical perspective on education efforts related to the environment at Michigan Tech. Flaws with the traditional and evolving education approach have been described. The traditional education of environmental engineering undergraduates has been largely focused on characterizing air/water quality and pollution control/containment. While a giant positive step forward, environmental courses designed for seniors/graduate students across the College of Engineering failed to fully discuss economic, societal, and policy topics. Masters students produced by the Environmental Policy program relied on a strong technical foundation from outside the program. In summary, traditional and even the updated educational programs in place at Michigan Tech by 2001 lacked a cohesive, organized structure. Furthermore, none of the students produced by the programs were fully trained to be strong in the sustainability triple bottom line (economic, societal and environmental sustainability).

As has been noted, throughout the 1990s a core group of faculty at Michigan Tech began developing environment-related course offerings. This group continued to expand over the years, with the number of participating disciplines increasing. The group began to undertake collaborative research activities generally focused on sustainability issues. Discussions related to sustainability have evolved and coalesced to form what we refer to as the Sustainable Futures Model (see Fig. 3). Sustainable Futures is focused on performing research and education in the following areas: 1) environmental systems, 2) industrial/manufacturing systems, 3) societal systems, and 4) integrative initiatives that involve the other three areas.

![Figure 3: Sustainable Futures Model](image-url)

Nurturing the development of the Sustainable Futures Model of course requires building relationships (and bridging gaps) between academic fields – this has been (and will continue to be) a major challenge for us. For over a century scientific progress has been predicated on decomposing large problems into small pieces and working on the individual small problems. Assembling the solutions to these small problems to produce a solution to the larger problem has generally not been a major aim of science/engineering – and, in fact, there is no...
guarantee that such assemblages will solve the larger problem. Society faces many large, complex problems and an intellectual challenge exists in developing methods for addressing such problems in a systematic way; establishing such methods requires an understanding of how fields imagine their own future and their role in problem resolution – such an understanding must be achieved to identify/ fill gaps between disciplines. Our experiences suggest that the use of a combination of shared proposal writing, research, and graduate teaching encourages progress in achieving this understanding, building collaborative ties, and bridging disciplinary gaps.

During the 1990s, rising concerns about the environment and ways to respond to human-induced changes to the natural world highlighted the need for social science/engineering relationships. Through these early relationships, it became clear that we did not share a common language, a similar idea of what constituted a research problem, a shared set of methods, or even a commitment to interdisciplinary research. A number of our early efforts fizzled or resulted in minor research activities. These smaller efforts yielded publications and conference papers, but failed to produce dramatic, campus-altering results. However, and this was important, we kept trying and we kept talking. Eventually a core set of collaborators emerged, creating a new network of on-campus colleagues who had begun to put all the missing pieces together.

While the efforts at collaborative research went on, the involved faculty started sharing teaching ideas, especially for graduate students. The M.S. in Environmental Policy, discussed above, was one by-product of this sharing, and added a missing dimension, as did growing capabilities in remote sensing and GIS. The School of Forestry added an undergraduate program in Applied Ecology. Both Forestry and Civil Engineering created extremely successful Peace Corps Masters programs. Eventually graduate students from the different departments began to take courses from the core set of faculty collaborators. Policy students took GIS or groundwater courses; engineering students took environmental decision-making and other policy courses. Over time, the faculty began to serve on thesis and dissertation committees for each other’s students.

As a result of the graduate teaching collaborations, the nature of the research and proposal writing activities changed somewhat. While smaller, focused, fundamental research proposals have continued, we have also begun to undertake large interdisciplinary proposal efforts in order to obtain block funding. Here the years of collaboration and teaching have proven extremely useful. For education-related initiatives/components we already have many relevant courses on the books. Where an element or new dimension was missing, our prior discussions and joint proposals/research permitted us to understand quickly what was needed from our relevant areas of expertise. We had built up enough trust and shared language so that we did not think it strange for professors from Chemical Engineering and Social Sciences to jointly design and offer a graduate Sustainability Seminar. Both had worked with each other for nearly a decade. We hope and expect that as the graduate training develops, we will learn more about how to teach and develop interdisciplinary courses and curricula.

At no point, have the members of the Sustainable Futures core faculty group abandoned their particular interests or fundamental areas of expertise. What happened was that we found new, interesting problems that benefited from our expertise. Only during the course of jointly working on problems have we added new dimensions and new applications for our specific knowledge areas. As for our graduate students, we are happy to report that they have a broader education than could be provided by any one faculty member or discipline.

**Sustainable Futures Education Program:**

As the Sustainable Futures faculty plans for the future and crafts a curriculum for our graduate students in the principles of sustainability, some background is in order. Masters students at Michigan Tech must take about 6 semester courses and complete a thesis in order to graduate (doctoral students generally take at least 6 courses as part of their program beyond their Masters). Given the desire to promote the broad perspective associated with Sustainable Futures, the challenge of doing this within a limited graduate curriculum, and the need to maintain a strong disciplinary focus, we have established a **Graduate Certificate in Sustainable Futures** that has the following requirements. All sustainable futures graduate students are required to take at least one course from each area within the core curriculum (see Fig. 4): Societal Systems, Industrial Systems, and Environmental Systems. Doctoral students in the program are required to take an additional two courses in Sustainable Systems (Sustainable Futures 1 and 2). The graduate certificate formally recognizes the student’s knowledge of the principles of Sustainable Futures.
Critical to the long-term success of Sustainable Futures is the cultivation of undergraduate interest in the activity. With this in mind, sustainability modules will be developed and taught to all incoming freshman in Michigan Tech’s common first-year engineering courses. The creation of these modules and courseware will be achieved by forming working groups between faculty, graduate students, and the first-year course instructors. A minor in “sustainability” will be developed and available for all undergraduate students.

Education – Beyond the University:

Most often faculty view their role to be principally focused on educating university students. Of course, this narrow viewpoint fails to recognize the important role of faculty, and universities in general, in promoting the general welfare of the populace. Toward this end, faculty educators should give some thought to the general state of knowledge of the public with respect to environmental issues. All the good works in the world with respect to environmental education and research will be for naught if the public remains uneducated with respect to some of the large environmental issues that the U.S. is faced with, or that are on the horizon. Although lengthy discussion of this issue falls well beyond the scope of this paper, we believe that the Sustainable Futures faculty has a role to play in educating the public. One way of depicting the relationship of Sustainable Futures to the public education challenge is shown in Fig. 5.

Figure 5 suggests that appropriate environmental information/education can be used to shape public actions that are sustainable. It is envisioned that faculty and universities have a role in not only helping to establish appropriate educational materials/information for societal consumption but also in judging the effectiveness of that communication (knowledge transfer). Efforts are currently underway by the Sustainable Futures faculty to address both of these needs.

**SUMMARY**

The importance of environmental, industrial/economic, and societal sustainability has been described. In spite of the importance of achieving the triple bottom line, university educational programs have been slow to respond. Students continue to be trained as experts in their discipline. Deficiencies of traditional environmental education programs at Michigan Tech as well as early collaborative environmental courses have been presented. The sustainable futures model has been introduced as a means for considering environmental, industrial/economic, and societal sustainability. A program that responds to the deficiencies in sustainability education has been presented. This
The program has been designed to serve the needs of social science, environmental engineering, and other science/engineering students from across the campus. Several key points from this paper include:

- The importance of the triple bottom line necessitates the establishment of educational programs in support of a new generation of engineers/scientists.
- All students must have at least a basic understanding of fundamental tenets of sustainability in terms of environmental, industrial/economic, and societal issues.
- The collaboration involved in creating a Sustainable Futures education program has also helped to nurture meta-disciplinary sustainability research at Michigan Tech.
- Educational programs have been established at both the graduate and undergraduate levels and efforts are now being directed at implementation.

Following the presentation of the new sustainability education paradigm, additional comments on the role of universities in creating an informed citizenry are presented.

REFERENCES


